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Proof Test Station

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Project Title: **Proof Test Station**

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Abstract/Summary

The purpose of the design project is to develop a proof test station to analyze the brazing process for a cold plate. The cold plate must be pressurized to 400 psig with air. Measurements must be taken on the top surface of the cold plate to verify that no more than 0.002” deflection has occurred. The test station needs to be user-friendly, automated, and adaptable to various sizes of cold plates ranging from 2”x2” to 8”x8”. The cold plate test station has to perform its test cycle in less than 45 seconds. Finally, the changeover time required to change the test station from testing one size of cold plate to another size of cold plate is less than five minutes.

The proof test station utilizes the following major components: Cartesian robot, laser displacement sensor (LDS), pneumatic guided cylinder, cold plate nest, nest sub-plate, sub-plate, table top, and human-machine interface (HMI). The sub-plate is attached to the table top using dowel pins for locating. The nest and nest sub-plate are attached to the sub-plate using 5/8” cross keyways as the locators. The cold plate is placed into the unique nest design. The pneumatic guided cylinder extends to the cold plate in order to secure the cold plate and to create an air tight seal. The Cartesian robot moves the LDS across a designated path on the top surface of the cold plate to take six measurements of the surface. The cold plate is pressurized to 400 psig by use of the air nozzle attachment on the pneumatic guided cylinder. A pressure transducer verifies the pressure exiting the cold plate is 400 psig by displaying the pressure reading on the HMI. The Cartesian robot takes a second pass with the LDS over the cold plate surface to measure the six locations once again. The HMI displays the original and final measurements of the LDS, and the difference between the two readings is displayed on the HMI. If one of the six locations has a difference of greater than 0.002” deflection, the location is turned red on the HMI, because the cold plate has failed the test station. The operator has to acknowledge the cold plate has failed before the test station will operate again. The pressure in the cold plate is released through an exhaust muffler, and the guided cylinder retracts. Now the cold plate can be removed.

Several tests were performed on the proof test station to assure it meets the needs of the company. First, a test was taken for the cycle time of the test station by having three group members operate the system to verify it was less than 45 seconds. The cycle times averaged a time of 37 seconds. Second, two group members performed changeovers on the test station to assure the changeovers require less than five minutes. The two changeovers averaged a time of 3 minutes and 20 seconds. Next, two cycles were performed by the test station for 10 second periods to verify the system will maintain 400 psig of air. The test station proved to hold a pressure of 416 psig for both tests. Finally, the test station took thirty LDS readings of a gauge block to determine the repeatability of the test station. A precision to tolerance ratio was calculated using the 30 measurement readings, which determined a value of 6.95%. The precision to tolerance ratio lies within the acceptable range used in industry.

The budget provided for the entire proof test station was $45,000. The actual cost of the proof test station minus labor and electrical component costs was $26,515.87. The group had $18,484.13 leftover when the project was completed.

A few recommendations can be provided after analyzing the final proof test station design. First, the weight of the Nest and Nest Sub-plate could be reduced to improve the ergonomics involved with changeovers of the test station. Or, handles could be added to the Nest Sub-plate to provide an easier method of changeovers. Second, a portion of the Nest could be removed to deter any possible destruction occurred when the guided cylinder attachment slams undesirably into the Nest. Next, the LDS should be protected by utilizing a larger Cartesian robot to retract the LDS from the Nest Sub-plate, so the operator cannot accidentally bump the LDS when performing a changeover. Also, more measurements can be taken of the cold plate top surface to insure any possible deflections in the surface are located and measured appropriately. Finally, a shelf should be added to the proof test station to provide a location for the unique Nests and Nest Sub-plates to be stored and easily accessed.

Section I: Detailed Description of the Selected Conceptual Design

Section 1.01 Mechanical Design

The final conceptual design utilized for the construction of the Proof Test Station for Parker Hannifin is a modified version of the initial conceptual designs envisioned in Senior Design Part 1. The test station uses a Human-Machine Interface (HMI) for the operator's controls. On the HMI, the operator selects the appropriate size cold plate. The Lexan entry door is opened, which deactivates the station by utilizing a safety interlock switch. The cold plate is placed into a nest uniquely designed for the cold plate to match the overall dimensions and the inlet/outlet port locations. Once the Lexan entry door is closed, the safety interlock switch activates the test station. The guided cylinder will extend until contact with the cold plate is made. The high pressure inlet fitting, which is attached to the guided cylinder, is squeezed against the inlet port of the cold plate, and it creates an air tight seal. The outlet port of the cold plate is squeezed against the nest outlet port in the rear of the nest due to the force created by the guided cylinder, which creates the final air tight seal for the setup. The Cartesian robot is activated once the cold plate sealing is completed. The Cartesian robot moves from its "home" location to the surface of the cold plate. The Cartesian robot follows a designated path around the cold plate specific to the size of cold plate. The Cartesian robot stops momentarily at various locations across the surface of the cold plate, and the laser displacement sensor (LDS) takes measurement readings during each stop of the Cartesian robot. The measurement readings are displayed on the HMI. After the initial measurement scan of the cold plate surface, the cold plate is pressurized to 400psig. A pressure transducer relays the pressure reading of the exiting air pressure of the cold plate to the HMI. If the pressure of the cold plate drops drastically below 400psig, the test process stops and a failure is notified on the HMI. This failure warning can designate a leaky cold plate or a failure to seal the cold plate. The operator must acknowledge the failure for the test station to be reactivated. If the pressure of the cold plate remains at roughly 400psig, the Cartesian robot will run an identical measurement scan path over the cold plate surface. The measurement readings from the final measurement scan for the specified locations are displayed on the HMI. A difference is taken between the final measurement scan and the initial measurement scan data, and the differences are displayed on the HMI. If the difference between any of the corresponding locations on the surface of the cold plate is greater than 0.002", the failed point on the cold plate is highlighted red. The operator must acknowledge the failed cold plate by pressing the acknowledgement button, so the test station will be reactivated. Once the Cartesian robot has completed both its initial and final measurement scans, the Cartesian robot returns to its "home" position. The air pressure in the cold plate is dumped through an exhaust muffler. After the air pressure is released from the cold plate, the guided cylinder retracts. At this point, the operator opens the Lexan entry door, which disables the test station, and the cold plate is removed from the test station and placed in either the successful or failure cold plate containers.

To change from the testing of one size of cold plate to another, the operator must unbolt the nest sub-plate and nest from the test station and remove these mounting components. The operator then selects the appropriate nest sub-plate and nest. These correct mounting components are installed using the cross keyway as the locator and the bolts for mechanically fastening the mounting components to the base plate. The nest outlet hose must be disconnected and reconnected during the change over process. Finally, the operator must select the appropriate size of cold plate on the HMI before beginning the test process.

Figure 1: Final Conceptual Design of Proof Test Station

Section 1.02 Parameters

The given parameters for the Proof Test Station as specified by Parker Hannifin have remained the same throughout the project. The first parameter for the test station is to provide a consistent air pressure of 400 psig in the cold plate during testing. The next parameter is to provide a test station with a change over time, the time required to change the test station from testing one size of cold plate to another, of no more than five minutes. Also, the test station must be able to process a single cold plate in less than forty-five seconds. Lastly and most importantly, the test station must be able to produce repeatable results in order to limit the frequency of false "failures" produced through the test station. These parameters will be further discussed at a later time, and the results of the parameters for the Proof Test Station will be revealed.

Section II: Building Procedure

Mechanical Fabrication

The mechanical fabrication consisted of assembling the mechanical components, pneumatic components, and electrical components. The proof test station was put together in a group effort by the maintenance department of Parker Hannifin and the IPFW senior design group members. The final design components were designed, selected, and finalized by the senior design group in collaboration with the Senior Manufacturing Engineer at Parker, Brad Beerman.

Section 2.01 Enclosure

The safety enclosure shown below in Figure 2 consisted of a combination of extruded aluminum pieces and clear Lexan sheets. The extruded aluminum were cut to specified lengths and then assembled to create the frame. The frame sits on top of wheels so that the station is mobile and can be moved and placed where needed inside the Parker Facilities. The front of the enclosure is two doors so that there can be full access to the inside set up. Located on the door is a safety interlock switch. This is used in sequence as the starting mechanism for the machine as well as a specified safety feature that was required. After the operator places a part into the set-up for test, once the door is shut that starts the testing procedure. If at any time the door is opened during test the test procedure will freeze at whatever step it is in.

Figure 2: Safety Enclosure

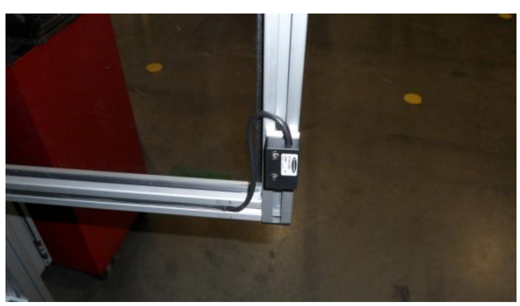


Figure 3: Interlock Switch

Section 2.02 Machined Components

(a) Table Top

The table top was made from 1/2” thick 1040 Steel and had dimensions of 32” x 39”. The table top was secured to the frame by using 1/2” socket head cap screws (SHCS) and is shown below in Figure 4. Some of the features of the table top were dowel holes that were used for precise placement of the robot mount, guided cylinder mount, and the base plate. The dowel pins help eliminate stack up tolerances and eliminate “play” in parts that would have just used bolts. A standard dowel pin is shown below in Figure 5. Another feature shown is a hole in the back left corner of the table top which is for the air lines and the wiring of the robot and the laser.

Figure 4: Machined Table Top

Figure 5: Dowel Pin

(b) Guided Cylinder Mount and Robot Mount

The guided cylinder mount and robot mount were both made 1040 Steel with a Black Oxide finish. The mounts were used to increase the height of the guided cylinder and the robot to make the system set up more adaptable to future cold plate designs. The mounts were secured to the table top using SHCS's and for precise placement dowel pins were used. Figure 6 below shows the installation of the dowel pins in the guided cylinder mount using an arbor press at the Parker facility.

Figure 6: Guided Cylinder Mount showing Dowel Pins

(c) Sub-Plate

The sub plate was also made out of 4140 pre hardened steel with a black oxide finish. The sub plate was secured to the table top using 5/16-18 SHCS and dowel pins were again used for precise alignment. There are also tapped holes on the top surface for the nest-sub plate to be bolted on top. There are two different set of holes which will be used for a 5” x 5” or a 10” x 10” nest-sub plates for smaller or larger cold plate designs. The smaller set of holes will be used for smaller cold plates and the larger holes will be for use in the larger cold plates. There is a 5/8” crossed key way that was created on the top surface to help align the nest-sub plate and the keys are actually bolted down in the key ways. The keys are show on the left of Figure 7 and it can be seen how the keys have countersunk holes for the #8-32 SHCS’s. The dowel pins and the cross key way are directly in line with the guided cylinder attachment air nozzle which is shown below in Figure 7.

Figure 7: Base Plate

(d) Nest Sub-Plate and Nest

Again 4140 pre hardened steel with a back oxide finish was used for the nest-sub plate and the nest. The nest-sub plate and nest act as an assembly specific to each size of cold plate. The bottom of the nest-sub plate has a cross key way to align it on the sub plate and counter sunk holes to bolt the nest to it which is shown in the left of Figure 8. The top surface shown on the right of Figure 8 has another cross key way with the keys bolted down which will help align the nest on the nest-sub plate.

Figure 8: Nest-Sub Plate

The nest was secured to the nest-sub plate using SHCS's and a cross key way for alignment. The nest was made thick enough to align the hole of the cold plate with the incoming air supply port on the guided attachment. Another feature of the nest is the port seal on the back of the nest. The fixture is threaded into the nest to a desired length and then a jam nut is used to secure the fixture in place. The last features to point out on the nest are the securing tabs. They are simply bolted onto the nest using SHCS's and are a safety measure to insure that the cold plate cannot move in the vertical direction during testing.

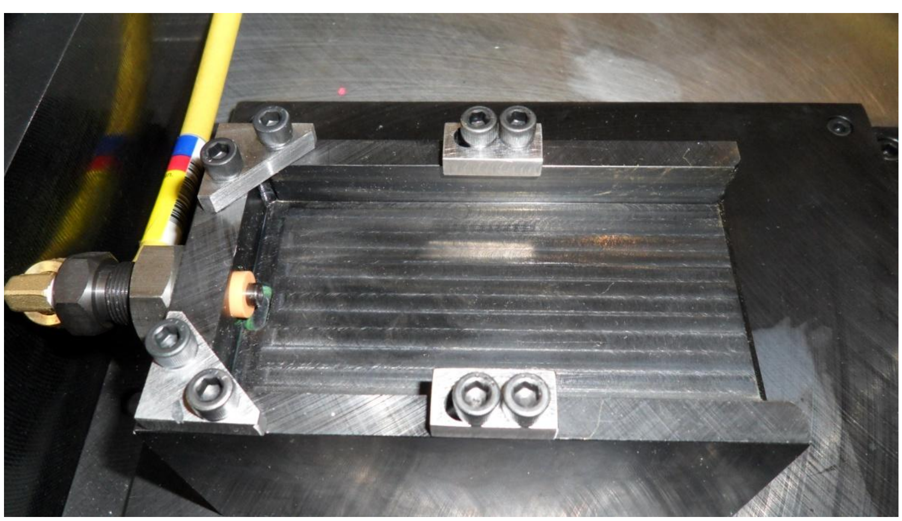


Figure 9: Nest

Figure 10 shows the outlet port that is used on the nest. A 90 degree fitting was used to then hook up the outlet air hose.

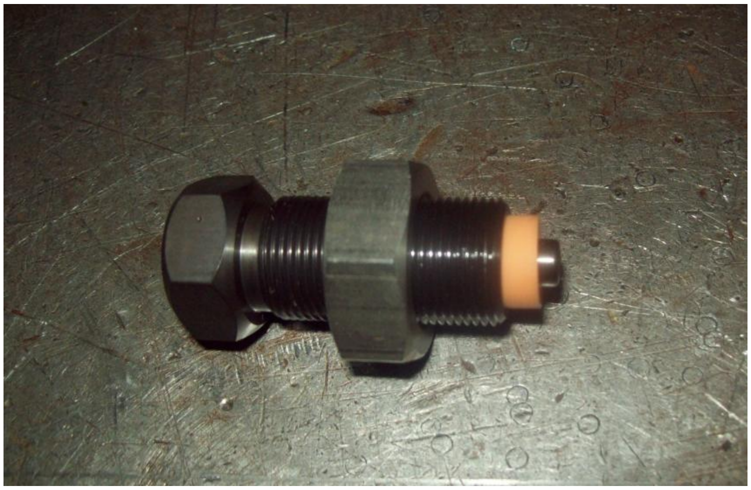


Figure 10: Nest Outlet Port

(e) Guided Cylinder Attachment

The guided cylinder attachment was made out of 4140 pre hardened steel with a black oxide finish. It was attached to the guided cylinder using SHCS's which were counter sunk and aligned using dowel pins to keep the alignment tight. An air line is attached to a side fitting and then there is an air port fixture attached on the front which will seal and deliver air to the cold plate. The air delivery fitting uses an o ring that acts as a face seal between the fitting and the guided cylinder attachment which keep the nozzle from leaking the high pressure air.

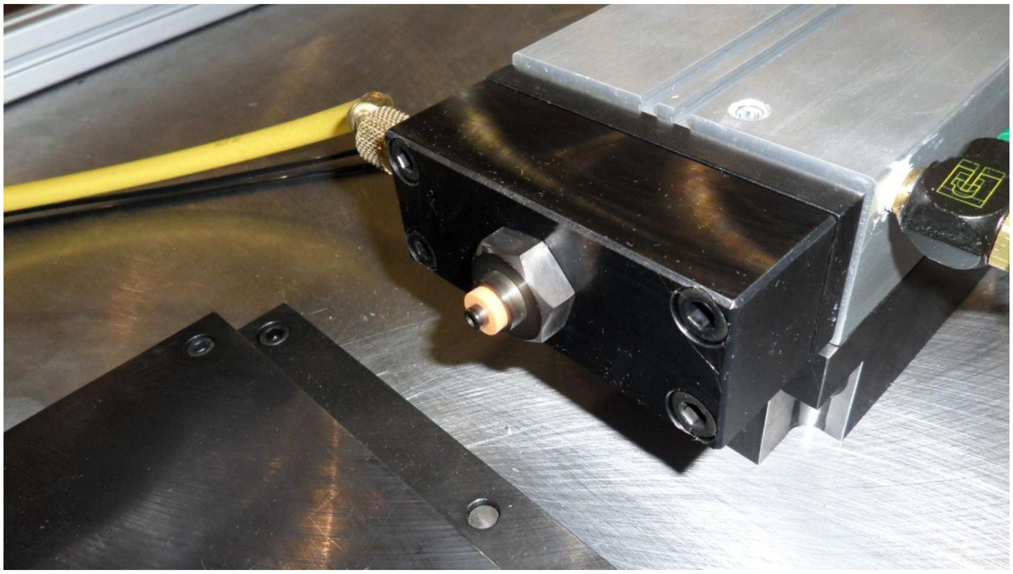


Figure 11: Guided Cylinder Attachment

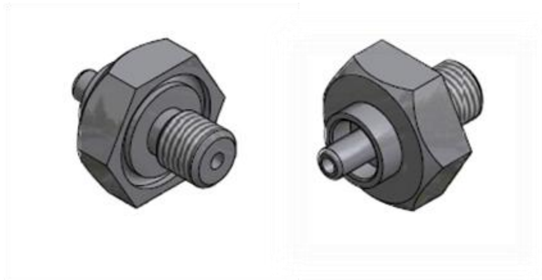


Figure 12: Air Import Fitting

(f) Laser Displacement Sensor Bracket

The LDS bracket was made of 4140 steel with a black oxide finish. For precise alignment of the laser the bracket had dowel pin holes that were used in mounting it to the Cartesian robot. Socket head cap screws were used to mount the laser to the bracket and to the robot.

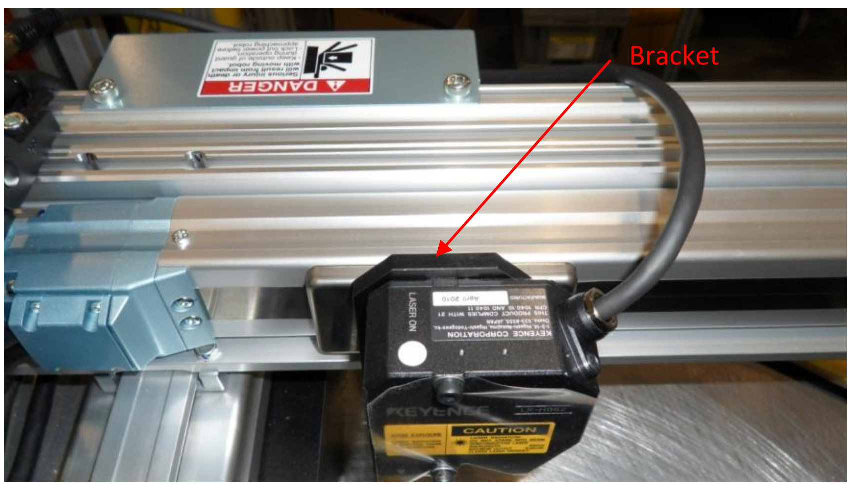


Figure 13: Laser Displacement Sensor Bracket

Section 2.03 Cartesian Robot

The Cartesian robot that was decided upon by the group was a Yamaha PXYx model. The robot met the requirements that were set in senior design I, which were a working area of 300 mm x 350 mm and a workable speed of around 600 $\frac{\mathrm{mm}}{\mathrm{s}}$ to 700 $\frac{\mathrm{mm}}{\mathrm{s}}$. The robot is used to carry the LDS over the cold plate.

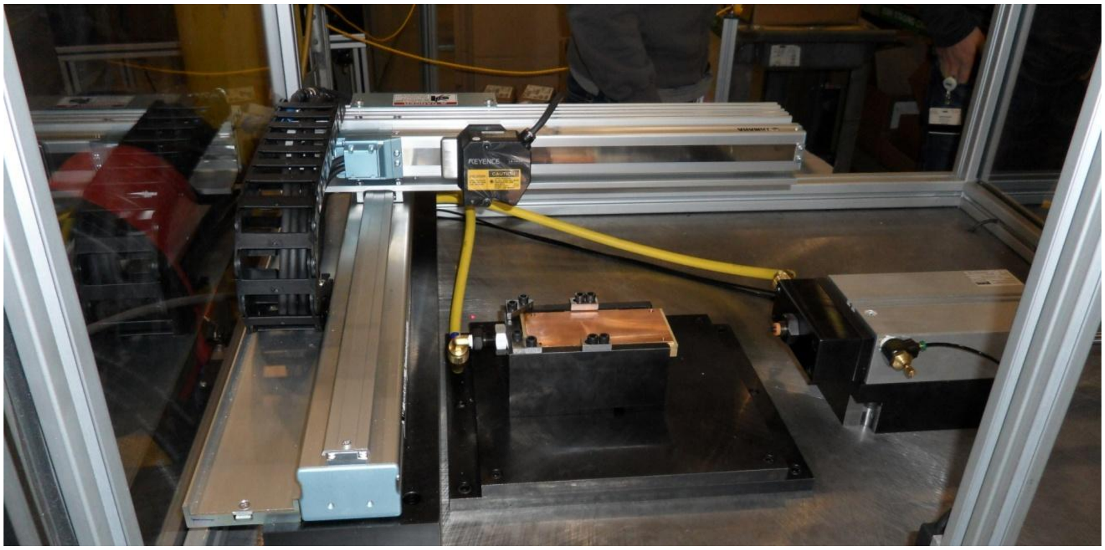


Figure 14: Cartesian Robot

Section 2.04 Laser Displacement Sensor

On the previous test stand that Parker Hannifin used they had contact sensors to measure the deflection on the cold plates. This is limited to locations that could be tested on the cold plates due to the fact they had to be fixed. We decided to go with a laser sensor and we chose the Keyence LK-G5000 Series.

Figure 15: Laser Displacement Sensor

Section 2.05 Guided Cylinder

The model that we chose to go with on the guided cylinder was a Parker P5T-J032SFSE150. We decided to go with a guided cylinder because of need for precise port placement for the incoming air supply. The guided cylinders use stainless steel rods that help stabilize and prevent deflection cylinder rod at anytime. The stroke length was 150 mm which will reach to the middle of the workable area of the Cartesian robot. Another feature that was chosen for the cylinder was the adjustable stop collars. The collars can be moved along the rods to shorten up the stroke length of the cylinder.

Figure 16: Guided Cylinder

Section 2.06 Pneumatic Design

The pneumatic design utilized both low pressure air and high pressure air of 60 psi and 400 psi respectively. The low pressure air was used to extend and retract the guided cylinder and the high pressure air was used for pressurizing the part.

Figure 17: Pneumatic Design

Section III: Testing

Measured Parameters:

Shown in Table 1 below are the parameters that were tested to verify that the test station met the requirements given to us by Parker. Cold Plate Pressure describes the internal pressure of the cold plate. This internal pressure must reach the given value to adequately test whether or not the cold plate has been brazed properly. Changeover time describes the time required to change the tooling from one size cold plate to another. This time must be reasonable because the operator's productivity will decrease if they have to spend several minutes completing this tooling changeover. The cycle time is the time required for the test station to complete its process of measuring the cold plate. The required time given to us is because these cold plates leave the brazing furnace approximately every 45 seconds so to keep up with the output of the furnace the cycle time must be 45 seconds or less. Last, the repeatability of the deflection measurement is the ability of the test station to consistently measure the deflection of the cold plate top surface. This value is determined using a normal distribution and will be discussed in further detail. This parameter is very important because the goal of the test station is to measure changes in deflection and if the measurement is not repeatable it we will not be able to accurately determine if the cold plate is brazed properly.

Table 1: Table of Tested Parameters

Test Parameters			
	Given	**Actual**	**Success Yes or No**
Cold Plate Pressure (psi)	400	416	Y
Maximum Changeover Time (min:sec)	5:00	3:20	Y
Cycle Time (s)	45	37	Y
Deflection Measurement Repeatablility (in.)	N/A	0.00016	Y

Section 3.01 Cold Plate Pressure

(a) Description

The cold plate pressure is a parameter given to us by Parker based on the procedure used previously to test whether the cold plate is brazed properly. To adequately test this brazing, the internal pressure of the cold plate must at least reach 400 psi. High pressure air enters the cold plate as shown in Figure 18 below. For our test, high pressure nitrogen was used instead of air because a high pressure air line was not available for our test. A pressure transducer measures the pressure at the exit of the cold plate. This pressure is measured at the exit to ensure that the 400 psi is reached throughout the entire cold plate. With this test the goal was to determine whether the internal pressure reached at least 400 psi and if the system held the 400 psi of pressure meaning there are no leaks.

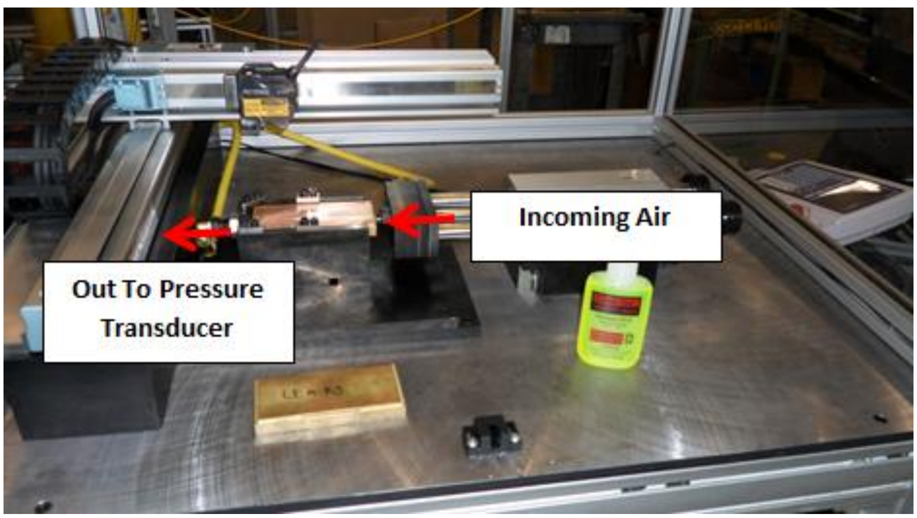


Figure 18: Cold Plate Pressure Test

(b) Test Procedure

The first couple of attempts to test the cold plate pressure were unsuccessful because the system would not hold the pressure. The pressure would reach the required 400 psi but after a few seconds it would drop meaning there was a leak somewhere in the system. It was determined that the leak was occurring around the edges of the fitting for the incoming air shown by the red arrows in Figure 19 below. This problem was fixed by simply tightening the fitting.

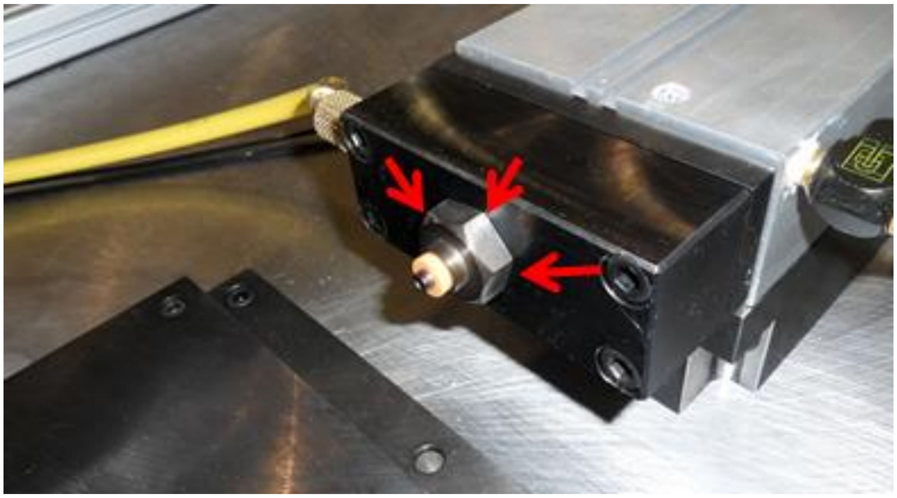


Figure 19: Fitting for Incoming Air

The test procedure was as follows:

1) Extend the clamping cylinder so that both ends of the cold plate are plugged.
2) Pressurize the cold plate until it reaches at least 400 psi.
3) Record the initial pressure and the pressure after 5 and 10 seconds. The pressure can be read from the screen shown in Figure 20 below.
4) Repeat steps 2 and 3 for second trial.

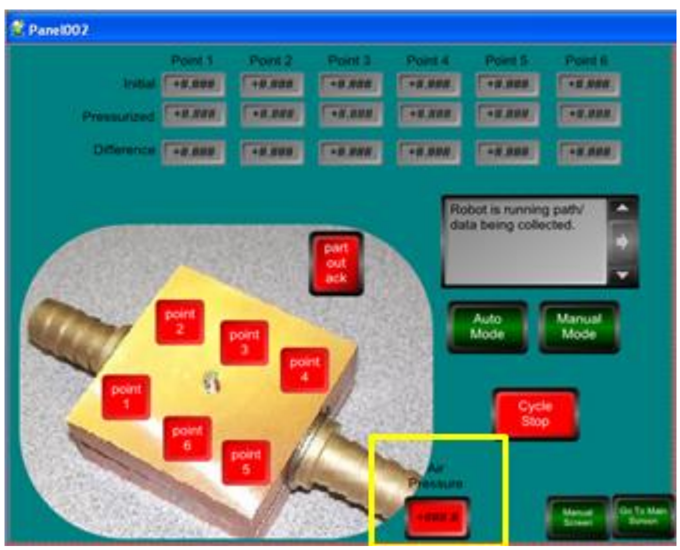


Figure 20: Operator Screen

(c) Results

The results for the pressure test are shown in Table 2 below. The test was a success because for both trials the pressure reached 416 psi which achieves our goal of reaching at least 400 psi and the pressure held constant for 10 seconds in both cases meaning that the cold plate was holding the air and the system was not leaking.

Table 2: Pressure Test Results

Cold Plate Pressure		
	Trial 1	Trial 2
Time (s)	Pressure (psi)	Pressure (psi)
0	416	416
5	416	416
10	416	416

Section 3.02 Maximum Changeover Time

(a) Description

The changeover time as described earlier is the time required for the operator to change the system over from testing one size heat to sink to another size. The requirement given to us by Parker was that the test station must be able to changeover to a different size in 5 minutes or less with minimal use of hand tools. The only hand tool required for our changeover is an Allen wrench. For a changeover the operator must complete the following steps:

1) Switch to manual mode by pressing the Manual Mode button on the operator screen shown below in Figure 21.

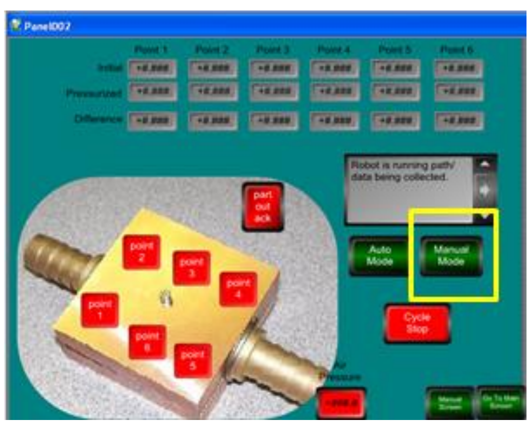


Figure 21: Manual Mode Button

2) Open the test station doors and remove any cold plates that may still be in the nest.
3) Unscrew the air hose from the exit port of the nest shown in Figure 22.

4) Remove the four screws shown by yellow arrows in Figure 22.

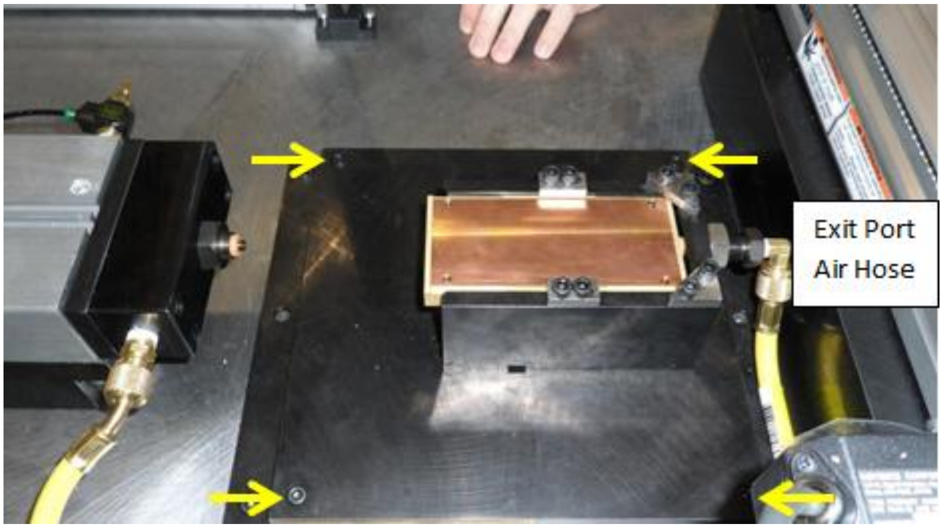


Figure 22: Cold Plate Tooling Screws and Air Hose

5) Remove the tooling as shown in
6)
7)

8) Figure 23.
9) Set the tooling below the test station and pick up new tooling.

Figure 23: Removal of Tooling

10) The key on the subplate shown in Figure 25 should fit in the keyway on the nest subplate shown in Figure 24.

Figure 25: Subplate Key

Figure 25: Nest Subplate Keyway

11) Replace the four screws removed previously and tighten them.
12) Screw the hose on the exit port back on.
13) Put the next cold plate to be tested in the nest and shut the test station doors.

(b) Test Procedure

For our test procedure each person followed the changeover process as described previously. A total of two trials were completed each with a different member of our team. We completed the changeover at a relaxed pace to get an idea of the maximum time required to complete the changeover. The time began as soon as the operator pressed the Manual Mode button and ended once the new cold plate had been placed in the nest and the doors shut.

(c) Results

The results for the Maximum Changeover Time test are shown in Table 3. According to the results our design was a success because we were given a maximum changeover time allowed of 5 minutes and our average changeover time was 3 minutes and 20 seconds which is well under the allowed time. Also, the only tool required is an Allen wrench which makes it easy for the operator.

Table 3: Changeover Time Test Results

Trial	Changeover Time (min:sec)
1	3:15
2	3:25
Average	3:20

Section 3.03 Cycle Time

(a) Description

The cycle time is the time from when the operator removes the old cold plate and replaces it with a new one to when the test station completes the measurement and the operator can remove the cold plate from the nest. This time includes the time for system to take an initial displacement reading, pressurize the part, and take a final displacement reading.

(b) Test Procedure

For our Cycle Time test we simply timed the cycle three different times and took the average of the times as our cycle time. The time started once the operator went to grab the cold plate and stopped once the measurement cycle completed and the operator went to grab the part that had been tested.

(c) Results

The results for the Cycle Time test are shown in Table 4. The results were a success because we had an allowed time of 45 seconds for the cycle and our average time was well below that at 37 seconds. The cycle time is a critical factor because a long cycle time can hurt productivity. Our cycle time will be more than adequate to keep up with the brazing furnace output of one part every 45 seconds.

Table 4: Cycle Time Test Results

Trial	Cycle Time (s)
1	38
2	37
3	36
Average	37

Section 3.04 Deflection Measurement Repeatability

(a) Description

The Deflection Measurement Repeatability is the most important aspect of our test station. Repeatability is defined as the variation in measurements taken by a single person or instrument on the same item and under the same conditions. This term is also called precision and is important because we are concerned with measuring the difference between deflection readings before and after pressurization and if the measurement is not repeatable we will not be accurately passing or failing the cold plates. We were not given a specific value that the repeatability had to be but based on industry standards we were able to evaluate whether or not the measurement system was able to accurately pass or fail cold plates.

(b) Test Procedure

For our test we used a gage block to measure. A program was used that took the laser back to its home position and then out to measure the block again. A total of 30 measurements were recorded.

Figure 26: Laser Taking Measurement

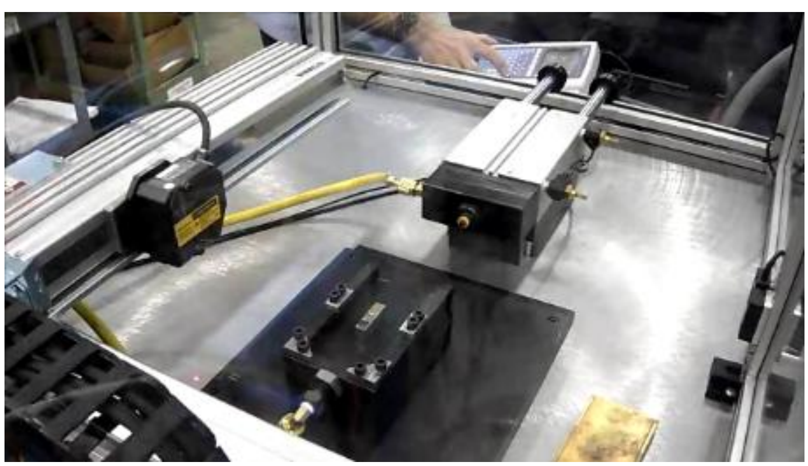


Figure 27: Laser in Home Position

(c) Results

The data for our 30 trials is shown below in Table 5. The measurement was taken in millimeters and was converted to inches by multiplying the measurement by 1 inch per 25.4 millimeters.

Table 5: Measurement Repeatability Data

Trial	Measurement (mm)	Measurement (in)	Trial	Measurement (mm)	Measurement (in)
1	0.159	0.006260	16	0.161	0.006339
2	0.160	0.006299	17	0.161	0.006339
3	0.159	0.006260	18	0.161	0.006339
4	0.160	0.006299	19	0.161	0.006339
5	0.159	0.006260	20	0.161	0.006339
6	0.160	0.006299	21	0.160	0.006299
7	0.161	0.006339	22	0.161	0.006339
8	0.160	0.006299	23	0.160	0.006299
9	0.161	0.006339	24	0.161	0.006339
10	0.161	0.006339	25	0.161	0.006339
11	0.161	0.006339	26	0.161	0.006339
12	0.160	0.006299	27	0.160	0.006299
13	0.161	0.006339	28	0.161	0.006339
14	0.161	0.006339	29	0.161	0.006339
15	0.161	0.006339	30	0.161	0.006339

Using a normal distribution we calculated the standard deviation using the following equation:

$$s = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(x_i - \overline{x})^2},$$

$$N = Number\ of\ Samples$$

$$x_i = Observed\ Value$$

$$\bar{x} = Sample\ Mean$$

The standard deviation was calculated to be 0.000027 inches. A typical standard used in industry to evaluate measurement systems is the Precision to Tolerance Ratio. The equation is as follows:

$$\frac{P}{T}\ Ratio = \frac{5.15 * \sigma}{Upper\ Spec\ Limit - Lower\ Spec\ Limit}$$

The value 5.15*σ is used as the precision because this is the interval that contains 99% of the probable measurement values. The tolerance used is the tolerance for the deflection of the top surface of the cold plate. The upper spec limit is 0.002 inches and the lower spec limit is 0. So the ratio is calculated as follows:

$$\frac{P}{T}\ Ratio = \frac{5.15 * 0.000027}{0.002 - 0} = 0.0695\ or\ 6.95\%$$

Industry defines P/T Ratios as follows:

P/T < 10%	Acceptable
10%<P/T<30%	Marginally Acceptable
P/T > 30%	Fail

According to this definition our measurement system would fall in the category of acceptable meaning our measurement method is successful at determining whether a part should pass or fail.

Section IV: Evaluation & Recommendations

Section 4.01 Evaluation

The proof test station has met the parameters discussed in the first senior design section. The cost was maintained below the quoted budget. The design is capable of handling various sized cold plates. Unlike the design from last semester, the current setup will accommodate cold plates with port holes on the bottom. The nest was raised high enough to allow hose connection from underneath. The different nest sizes were not built during the semester, but can be made if Parker decides to test other cold plates. The design was intended to fit cold plates up to 8" x 8" in size. The nest was raised to allow the use of cold plates with ports on the bottom.

The cycle time was measured to be between 30 and 40 seconds; below the goal of 45 seconds. It has been housed in lexan plexiglass for protection and optimal visibility. The interlock switch prevents the machine from operating once the door has been opened. In order to change the cold plate size, an Allen wrench is needed. Four mounting bolts must be removed and the air hose needs to be disconnected. The air hose must be manually unscrewed to remove the plate. The changeover time meets the requirement of being less than five minutes and it is done with minimal us of hand tools.

The guided cylinder support that mounts the thruster to the table needed to be modified. Originally there was no way for the guided cylinder to mount to the support and onto the table. The corners were machined out to allow access for the bolts.

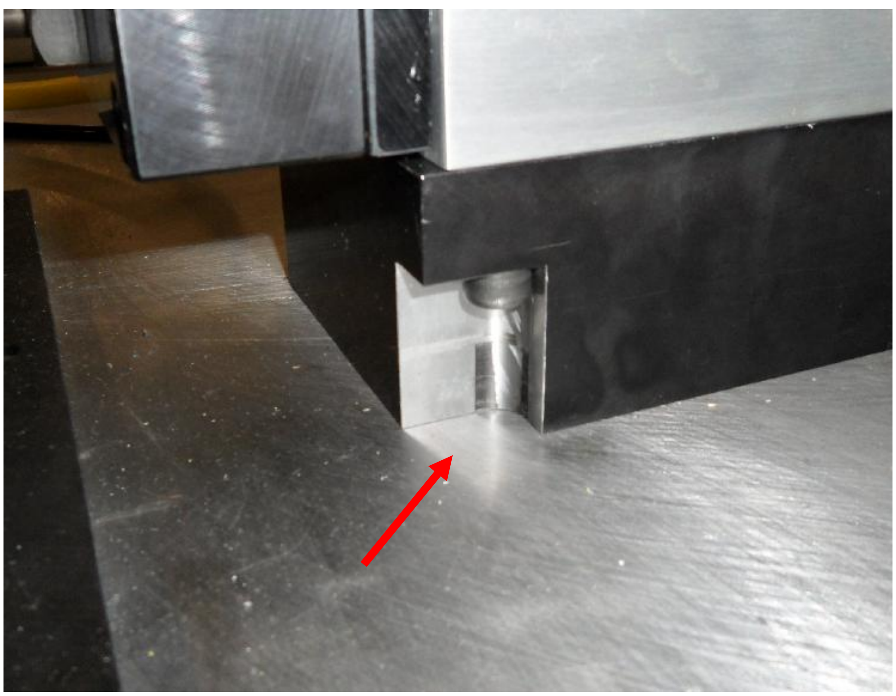


Figure 28: Modification of guided cylinder mount

The robot was tested for repeatability and found to be accurate. The pressure in the cold plate was confirmed to be at least 400 psi after numerous trials.

Section 4.02 Recommendations

The next section is dedicated to the possible changes that the group would have made if the project were taken further.

(a) Machine execution without cold plate

One potential problem with the current design is the clearance between the nest and the guided cylinder nozzle. If the machine is run without a cold plate, the guided cylinder nozzle will be pressed into the bottom of the nest. This has the potential to cause damage to the nozzle tip or nest. A solution would be to add stop collars to the back of the guided cylinder to prevent movement beyond the edge of the nest. This would cause more changeover time for adjusting to a specific cold plate size. Another solution would be to cut out the area on the nest where the guided cylinder would make contact if the cold plate was missing.

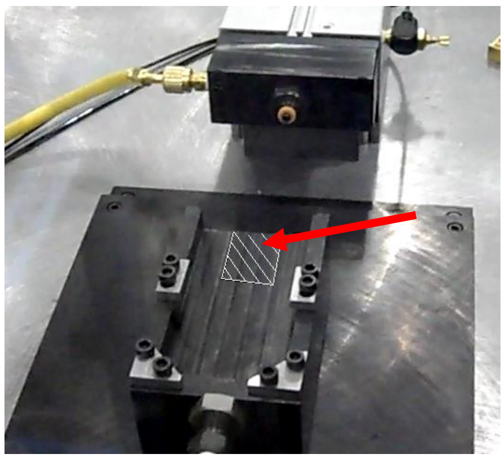


Figure 29: Removed Area

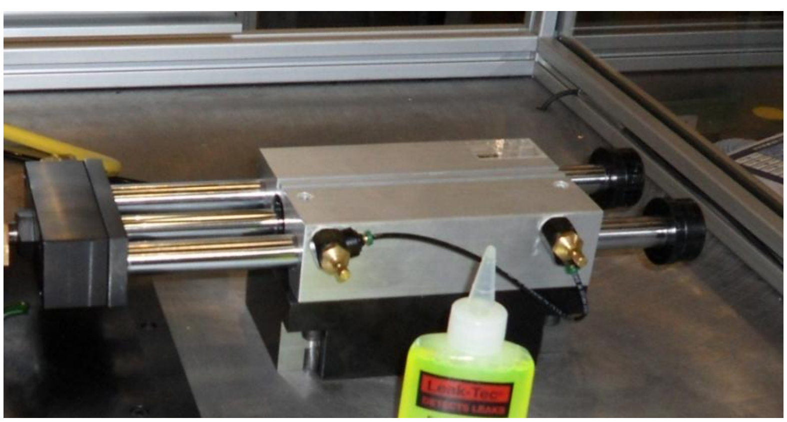


Figure 30: Stop Collars

(b) Protection of the LDS

During the changeover of the nest it became apparent that the location of the LDS sensor was too close to the mounting bolts. This may cause damage to the sensor if it makes contact with the plate during removal. The recommendation is to use a larger robot with more room to locate the sensor further away from any contact point.

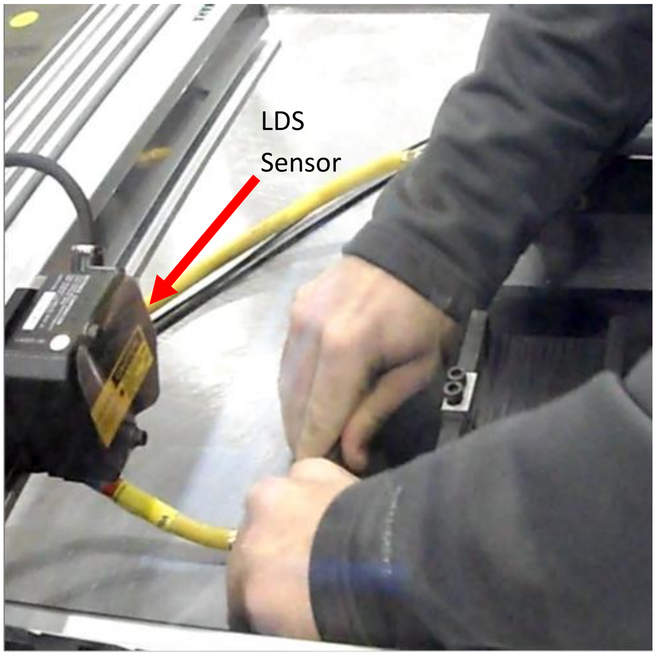


Figure 31: Operator's hands are close to LDS sensor

(c) More measurement points

The current software has been programmed to take six points of measurement. If more points prove to be necessary the program can be updated to take more measurements. The tradeoff is a longer cycle time.

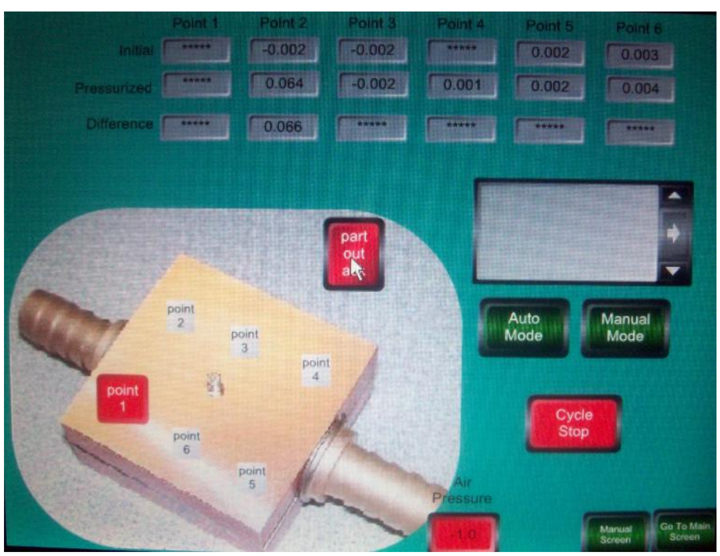


Figure 32: Current program screen with six points of measurement

(d) Difficulty reconnecting the air hose to the nest

During the changeover process, it was challenging to reconnect the hose on the newly installed nest. This can be fixed by installing quick release fittings. Unfortunately it would not be possible to move the nest away from the robot because it would be outside of the robots working envelope.

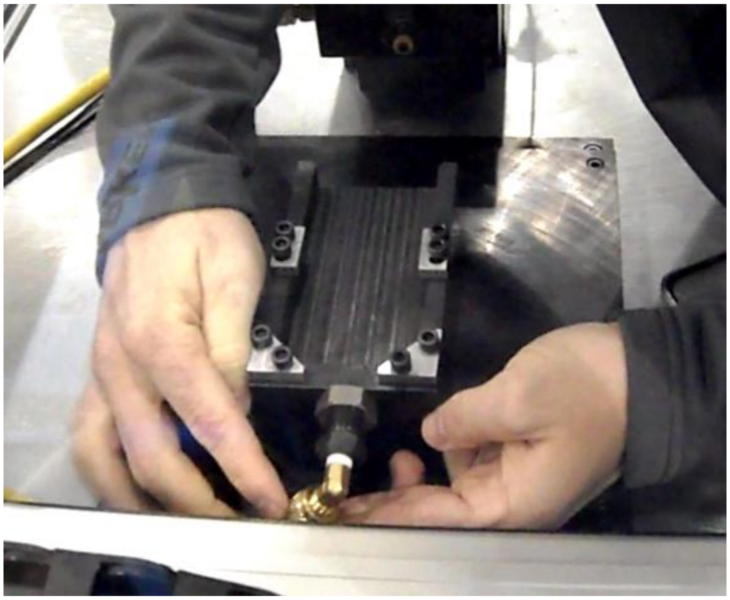


Figure 33: Difficult location for reconnection of air hose

(e) Addition of shelves

Currently there is no place to store the extra nests for different sized cold plates. Adding a shelf below the table top to store these nests would increase the changeover time and give the operator a place to store tools and testing related items.

Figure 34: Proposed location of shelf

(f) Addition of handles to remove heavy tooling

The nest was made of solid steel with a black oxide finish. It was noticed during changeover that the weight of the removed component was heavier than anticipated. Currently, the nest is removed by grasping the raised section. There is a potential for dropping the nest and sub plate upon removal. To reduce this risk, it is proposed that handles be added to each side of the sub plate. The operator can then manage the weight in an easier fashion.

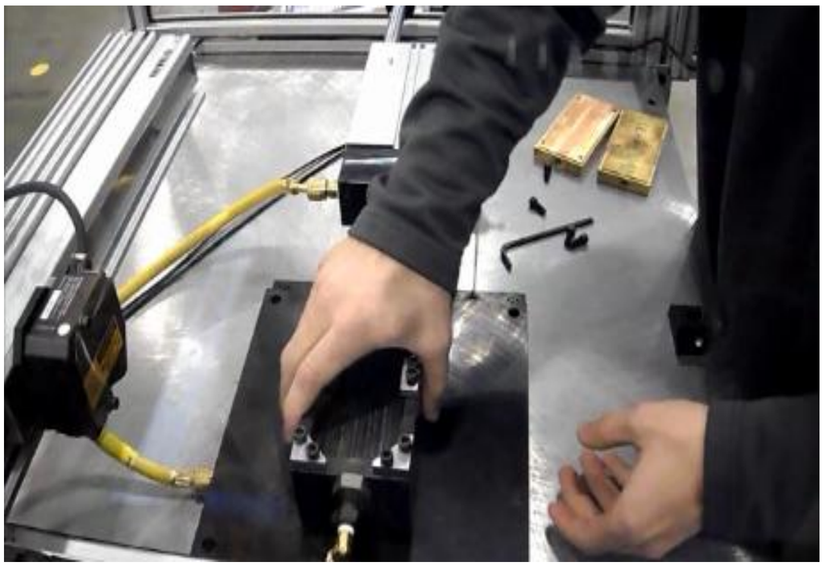


Figure 35: Nest Removal

Conclusion

The project allowed these students to manage a project from beginning to end. They had to work together as a team to achieve the best possible solution under the given constraints. It was a good opportunity to learn how to create drawings for correct machining. This included what tolerances to use and what instructions were needed. The exposure to the Parker plant gave insight into the industry standards and practices used for similar test stations. The planning and timing were done in conjunction with the lead time to receive all of the components. The students had to adapt accordingly and create testing procedures within the allotted time.

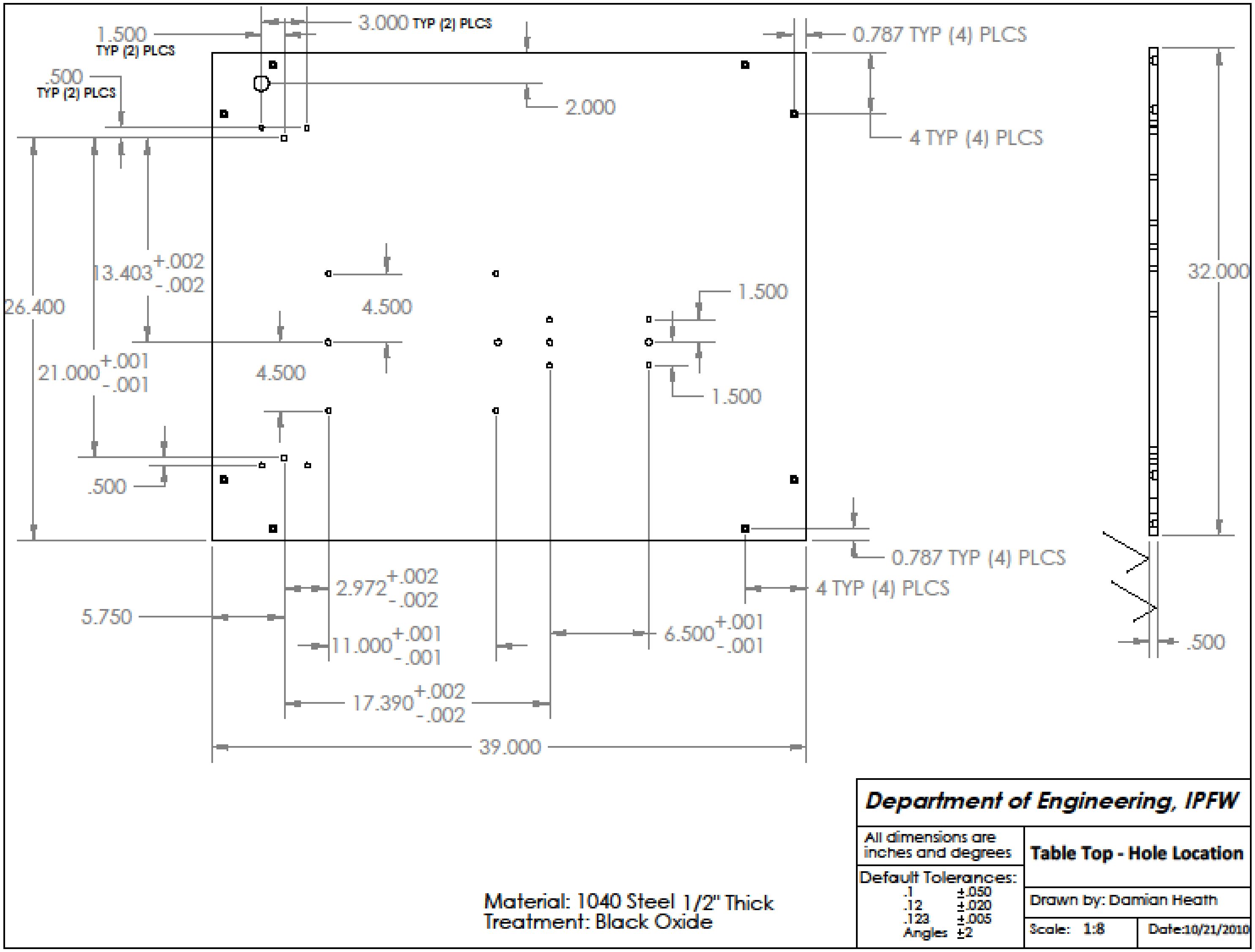
The calculations were done using classes that the students had taken prior to the project. SolidWorks® (ME160) was crucial in developing a model and creating drawings for machining. Strength of materials (ME250) was used to confirm that the framework would hold the weight of the table and its components. Machine design (ME369) was needed to analyze the keyways and mounting bolts. Statistics (STAT 511) helped analyze the data from testing. The data had to be interpreted to confirm the validity of the results. Measurements and instrumentation (ME293) provided the procedure for developing the type of experiment to conduct.

The final test stand met all of the requirements. It was below the budget set by Parker, completed within the required time and ran successfully. The students are pleased with the results and plan to use the experience in future job related projects.

References

1. http://www.accuratescrew.com/info/SocketRef.aspx
2. Hamrock, Bernard J. *Fundamentals of Machine Elements*. 2nd ed. New York, NY: McGraw-Hill Companies Inc., 2005. 707-764. Print
3. Oberg. *Machinery's Handbook*. 28th ed. 2008. Print.
4. Morris, Don H. *Mehcanics of Materials*. 6th ed. John Wiley & Sons Inc., 2006. Print.
5. *http://www.industrialmuscle.co.uk*
6. http://www.omega.com/ppt/pptsc.asp?ref=LD620
7. http://www.pewa.panasonic.com
8. http://www.parker.com/
9. http://www.granateseed.com/futilepodcast/wp-content/uploads/robot-arm.jpg

Appendix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3.000 TYP (2) PLCS
0.787 TYP (4) PLCS
.500
TYP (2) PLCS
2.000
4 TYP (4) PLCS
13.403 +.002 -.002
26.400
4.500
1.500
32.000
21.000 +.001 -.001
4.500
1.500
.500
0.787 TYP (4) PLCS
2.972 +.002 -.002
4 TYP (4) PLCS
5.750
11.000 +.001 -.001
6.500 +.001 -.001
.500
17.390 +.002 -.002
39.000
Department of Engineering, IPFW
All dimensions are inches and degrees
Table Top - Hole Location
Default Tolerances:
.1 ±.050
.12 ±.020
.123 ±.005
Angles ±2
Drawn by: Damian Heath
Scale: 1:8
Date:10/21/2010
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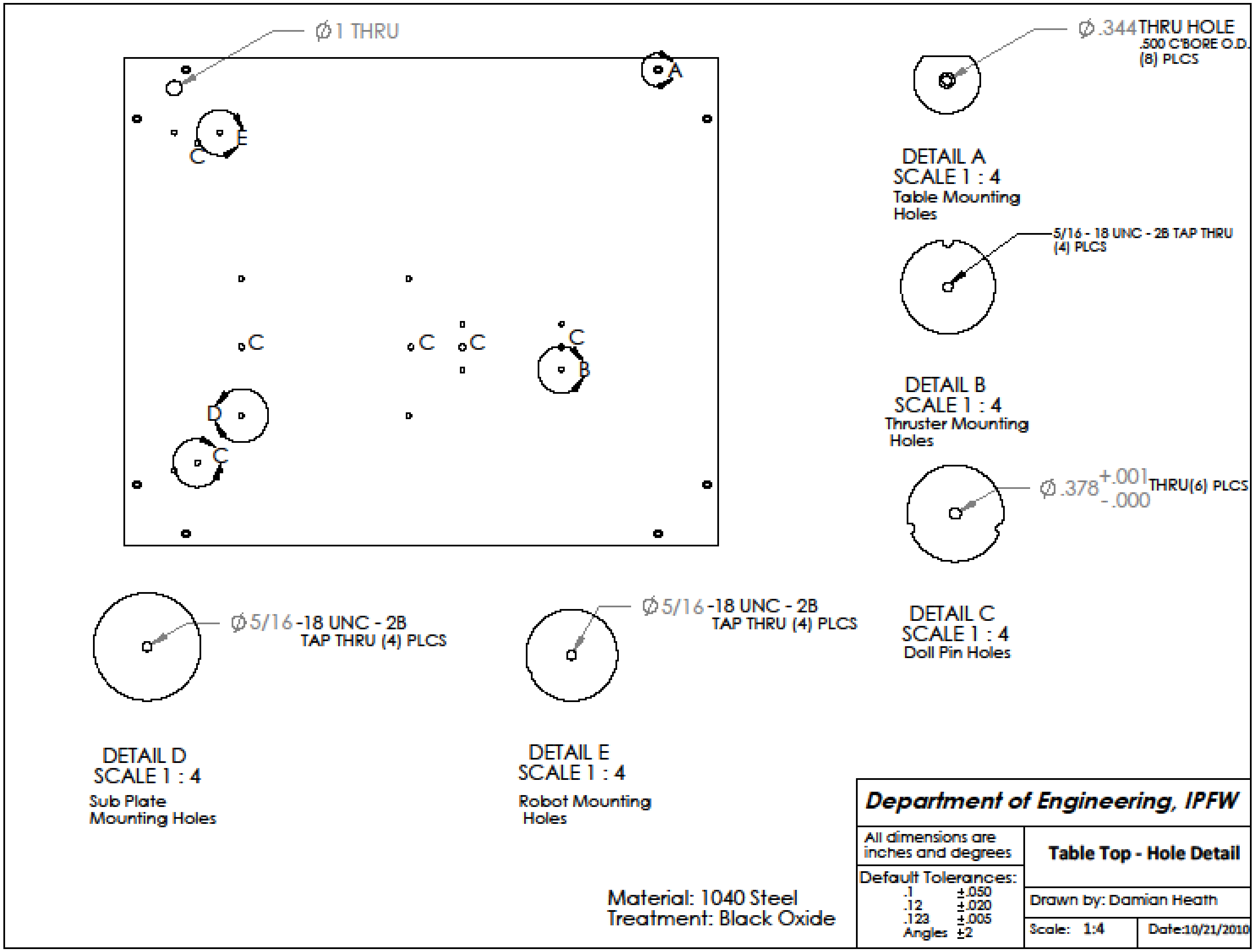
Treatment: Black Oxide



Ø1 THRU
A
E
C
C
C
C
C
B
D
C
Ø.344 THRU HOLE
.500 C'BORE O.D.
(8) PLCS
DETAIL A
SCALE 1 : 4
Table Mounting Holes
5/16 - 18 UNC - 2B TAP THRU
(4) PLCS
DETAIL B
SCALE 1 : 4
Thruster Mounting Holes
Ø.378 +.001 -.000 THRU(6) PLCS
DETAIL C
SCALE 1 : 4
Doll Pin Holes
Ø5/16-18 UNC - 2B
TAP THRU (4) PLCS
DETAIL D
SCALE 1 : 4
Sub Plate Mounting Holes
Ø5/16-18 UNC - 2B
TAP THRU (4) PLCS
DETAIL E
SCALE 1 : 4
Robot Mounting Holes
Material: 1040 Steel
Treatment: Black Oxide
Department of Engineering, IPFW
All dimensions are inches and degrees
Table Top - Hole Detail
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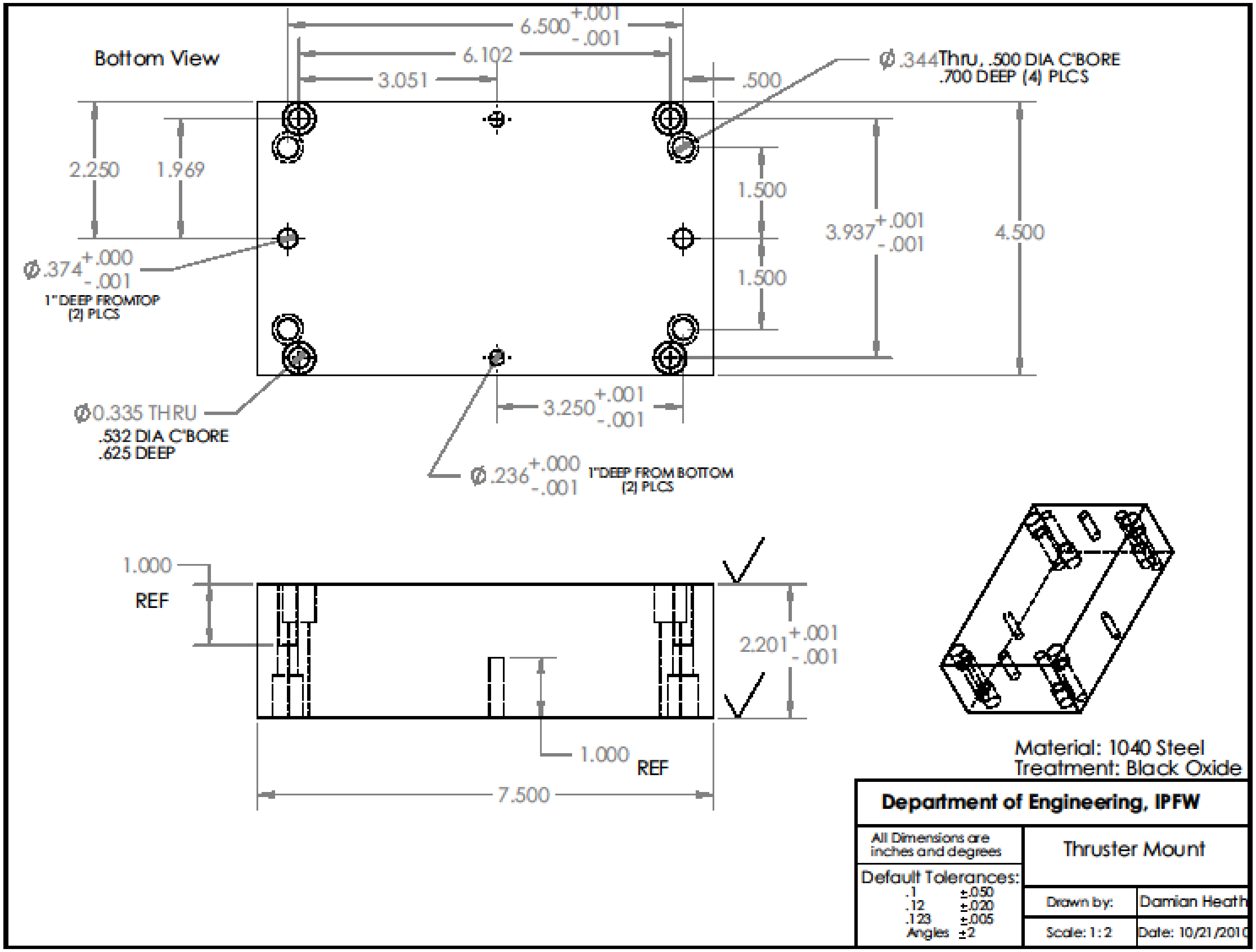
.12 ±.020
.123 ±.005
Angles ±2
Drawn by: Damian Heath
Scale: 1:4
Date:10/21/2010


Bottom View
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6.102
3.051
.500
Ø.344Thru, .500 DIA C'BORE
.700 DEEP (4) PLCS
2.250
1.969
1.500
1.500
3.937 +.001 -.001
4.500
Ø.374 +.000 -.001
1"DEEP FROMTOP
(2) PLCS
Ø0.335 THRU
.532 DIA C'BORE
.625 DEEP
3.250 +.001 -.001
Ø.236 +.000 -.001
1"DEEP FROM BOTTOM
(2) PLCS
1.000
REF
2.201 +.001 -.001
1.000
REF
7.500
Material: 1040 Steel
Treatment: Black Oxide
Department of Engineering, IPFW
All Dimensions are inches and degrees
Thruster Mount
Default Tolerances:
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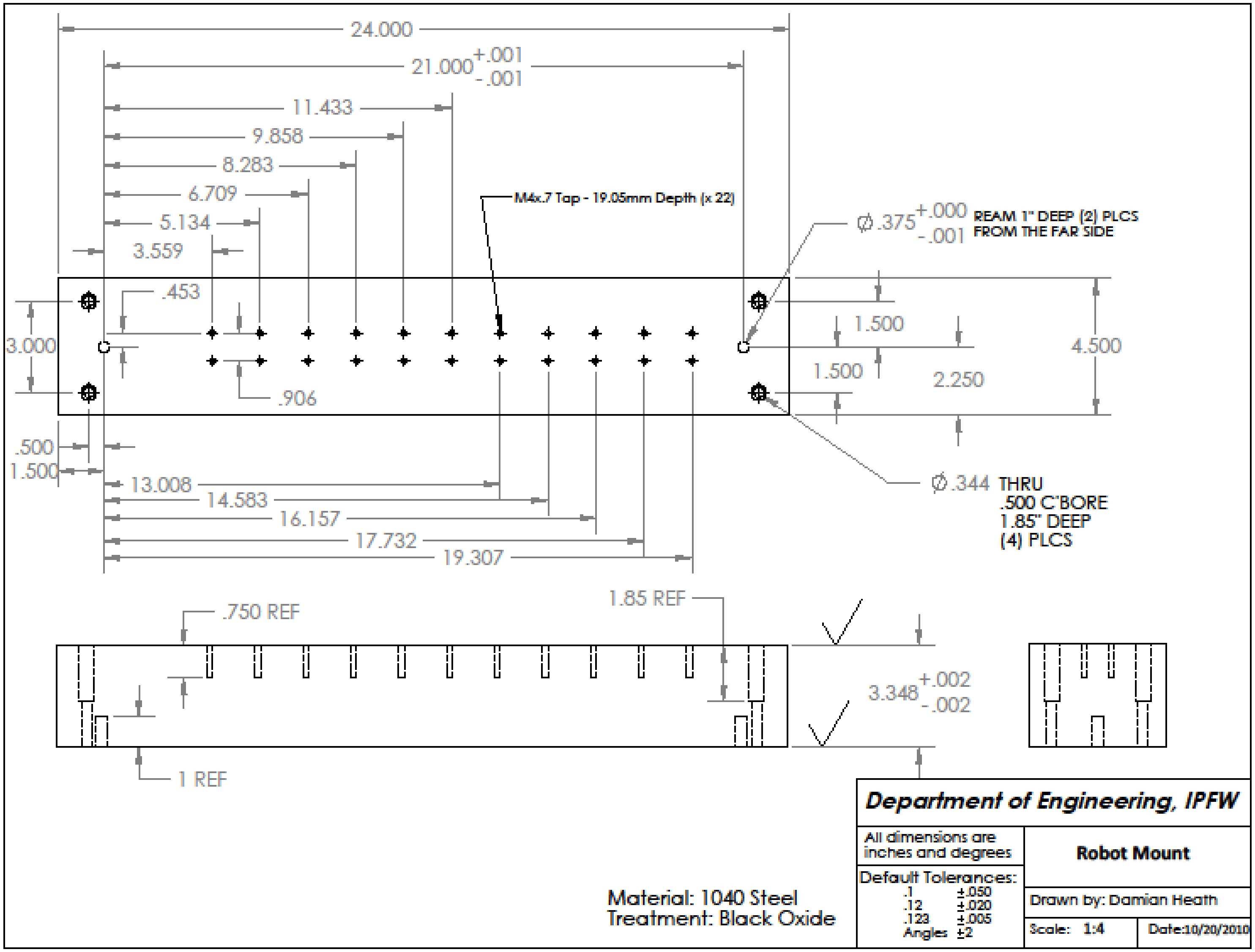
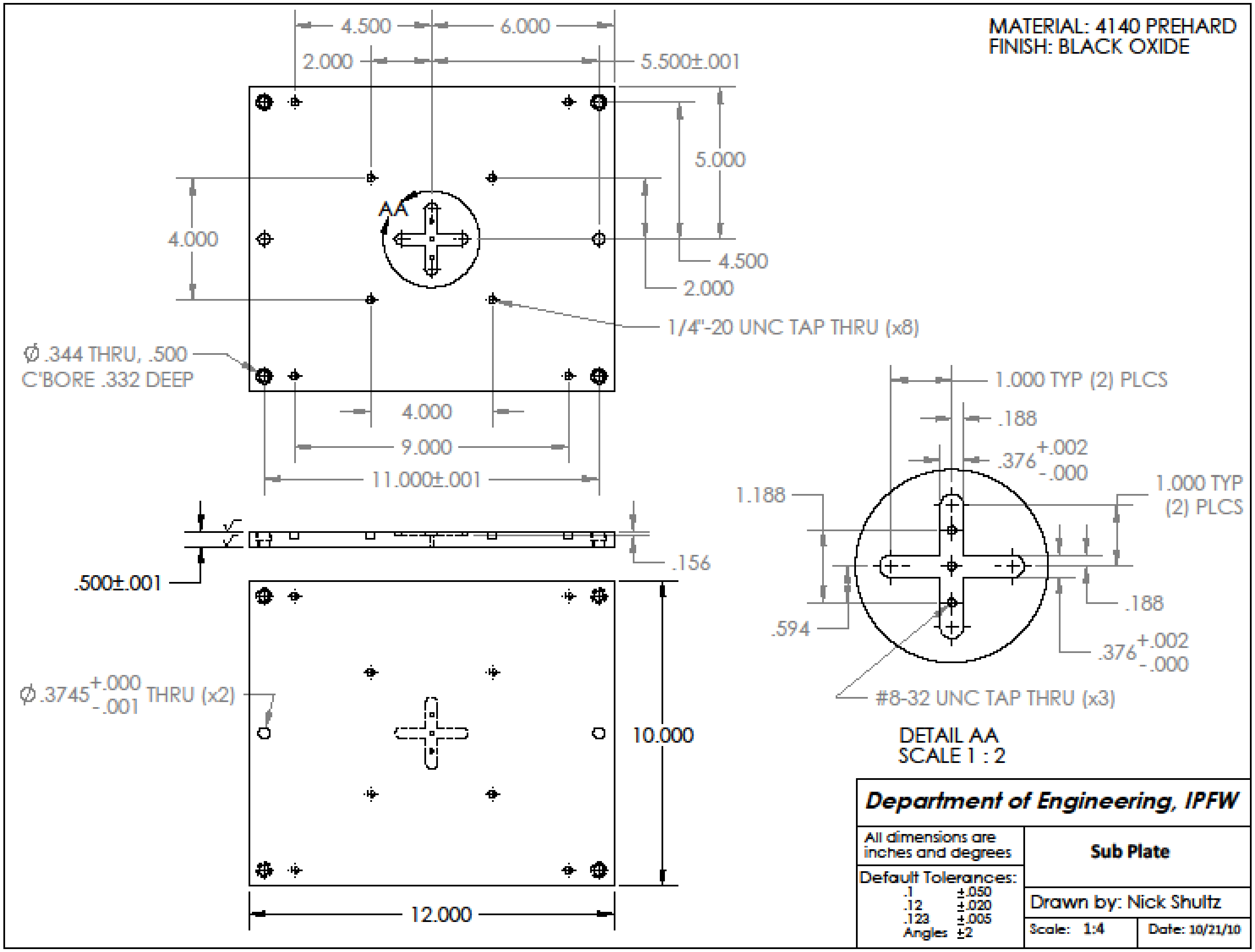
.12 ±.020
.123 ±.005
Angles ±2
Drawn by: Damian Heath
Scale: 1:2
Date: 10/21/2010


24.000
21.000 +.001 -.001
11.433
9.858
8.283
6.709
5.134
3.559
M4x.7 Tap - 19.05mm Depth (x 22)
∅.375 +.000 -.001 REAM 1" DEEP (2) PLCS FROM THE FAR SIDE
.453
3.000
1.500
1.500
2.250
4.500
.906
.500
1.500
13.008
14.583
16.157
17.732
19.307
∅.344 THRU
.500 C'BORE
1.85" DEEP
(4) PLCS
.750 REF
1.85 REF
3.348 +.002 -.002
1 REF
Material: 1040 Steel
Treatment: Black Oxide
Department of Engineering, IPFW
All dimensions are inches and degrees
Robot Mount
Default Tolerances:
.1 ±.050
.12 ±.020
.123 ±.005
Angles ±2
Drawn by: Damian Heath
Scale: 1:4
Date:10/20/2010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FINISH: BLACK OXIDE
4.500
6.000
2.000
5.500±.001
5.000
4.000
AA
4.500
2.000
1/4"-20 UNC TAP THRU (x8)
Ø .344 THRU, .500
C'BORE .332 DEEP
4.000
9.000
11.000±.001
.500±.001
.156
Ø .3745 +.000 -.001 THRU (x2)
10.000
12.000
1.000 TYP (2) PLCS
.188
.376 +.002 -.000
1.188
1.000 TYP
(2) PLCS
.188
.594
.376 +.002 -.000
#8-32 UNC TAP THRU (x3)
DETAIL AA
SCALE 1 : 2
Department of Engineering, IPFW
All dimensions are inches and degrees
Sub Plate
Default Tolerances:
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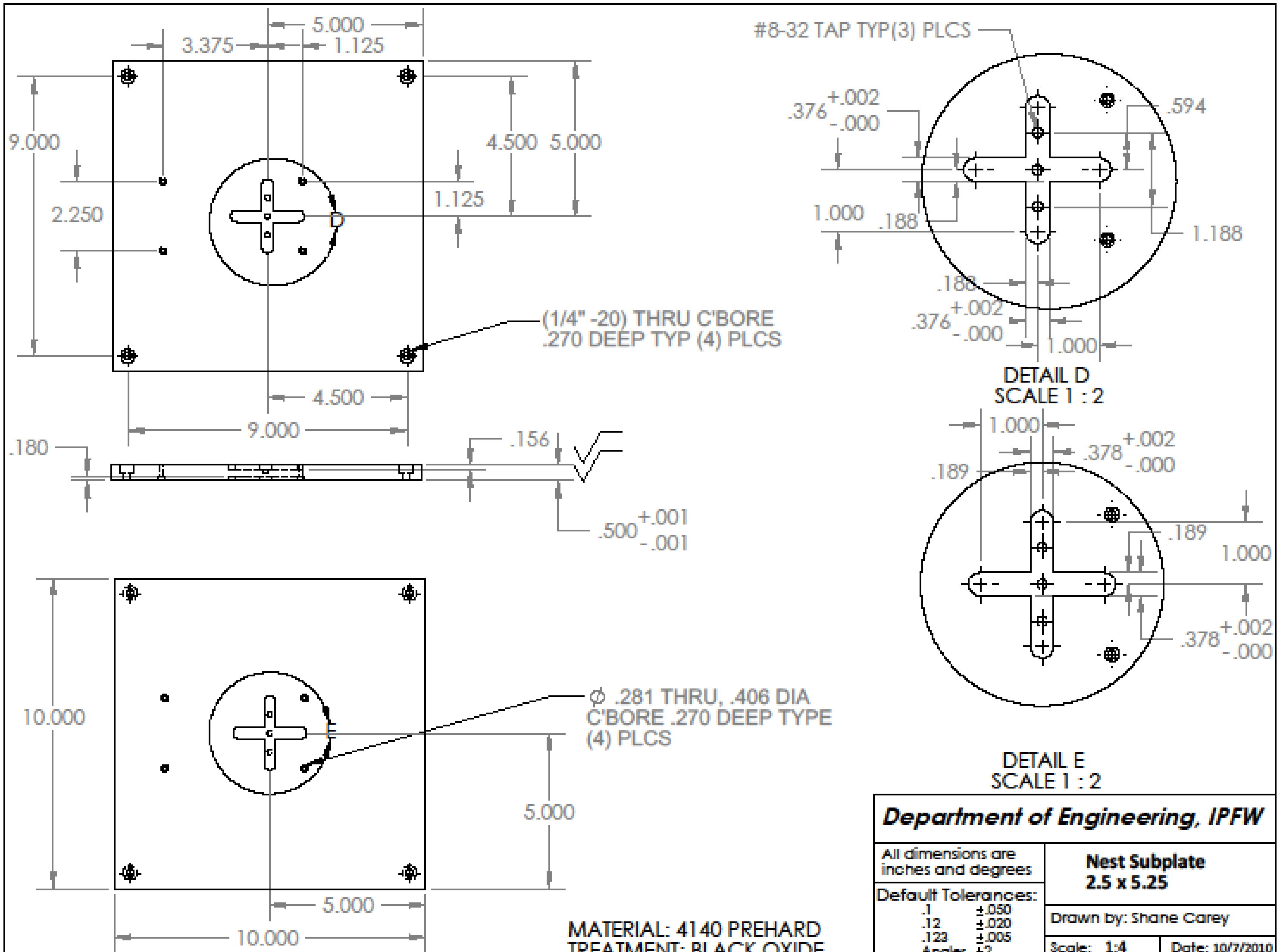
.12 ±.020
.123 ±.005
Angles ±2
Drawn by: Nick Shultz
Scale: 1:4
Date: 10/21/10



MATERIAL: 4140 PREHARD
TREATMENT: BLACK OXIDE

Department of Engineering, IPFW	
All dimensions are inches and degrees	**Nest Subplate 2.5 x 5.25**
Default Tolerances: .1 ±.050; .12 ±.020; .123 ±.005; Angles ±2	Drawn by: Shane Carey
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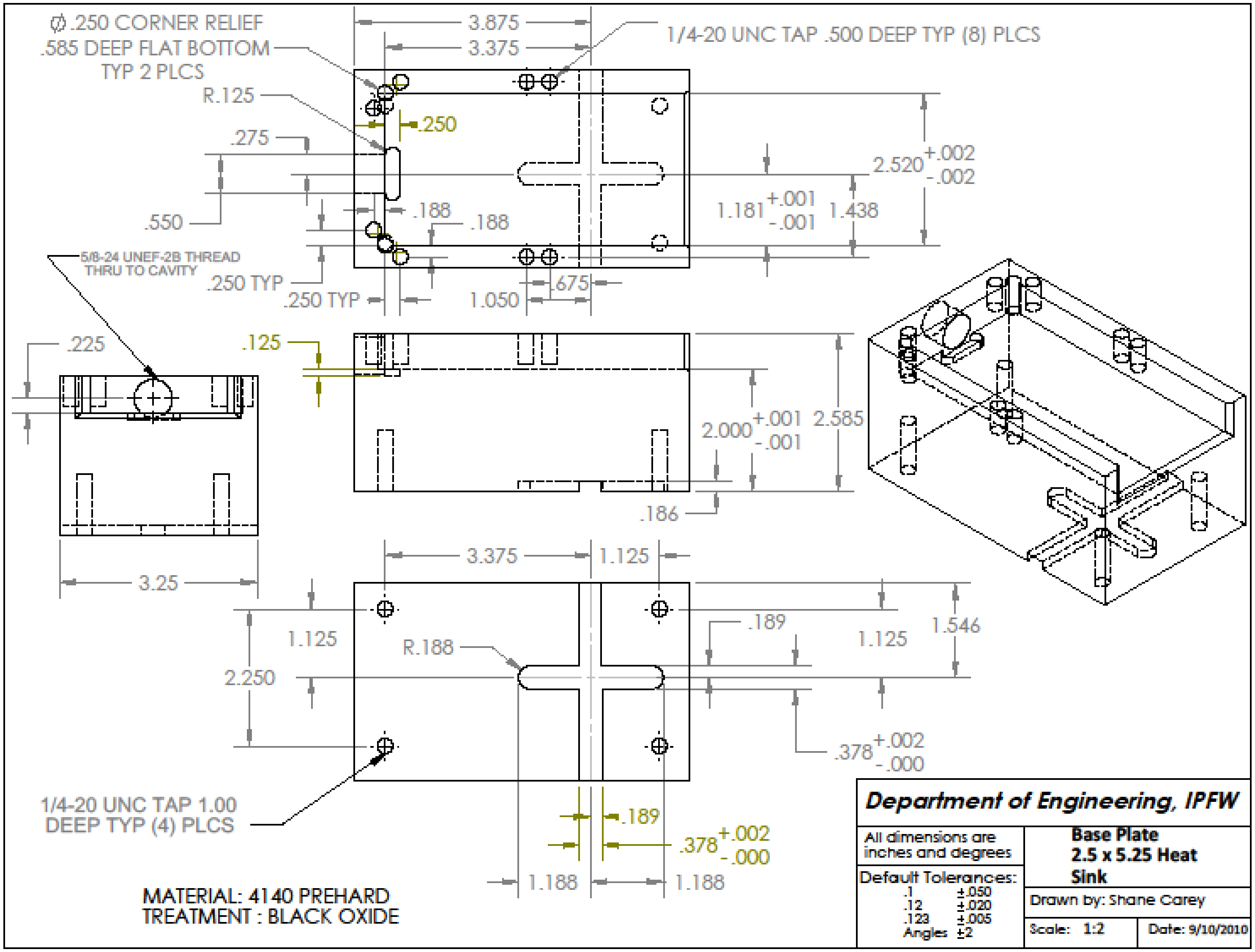
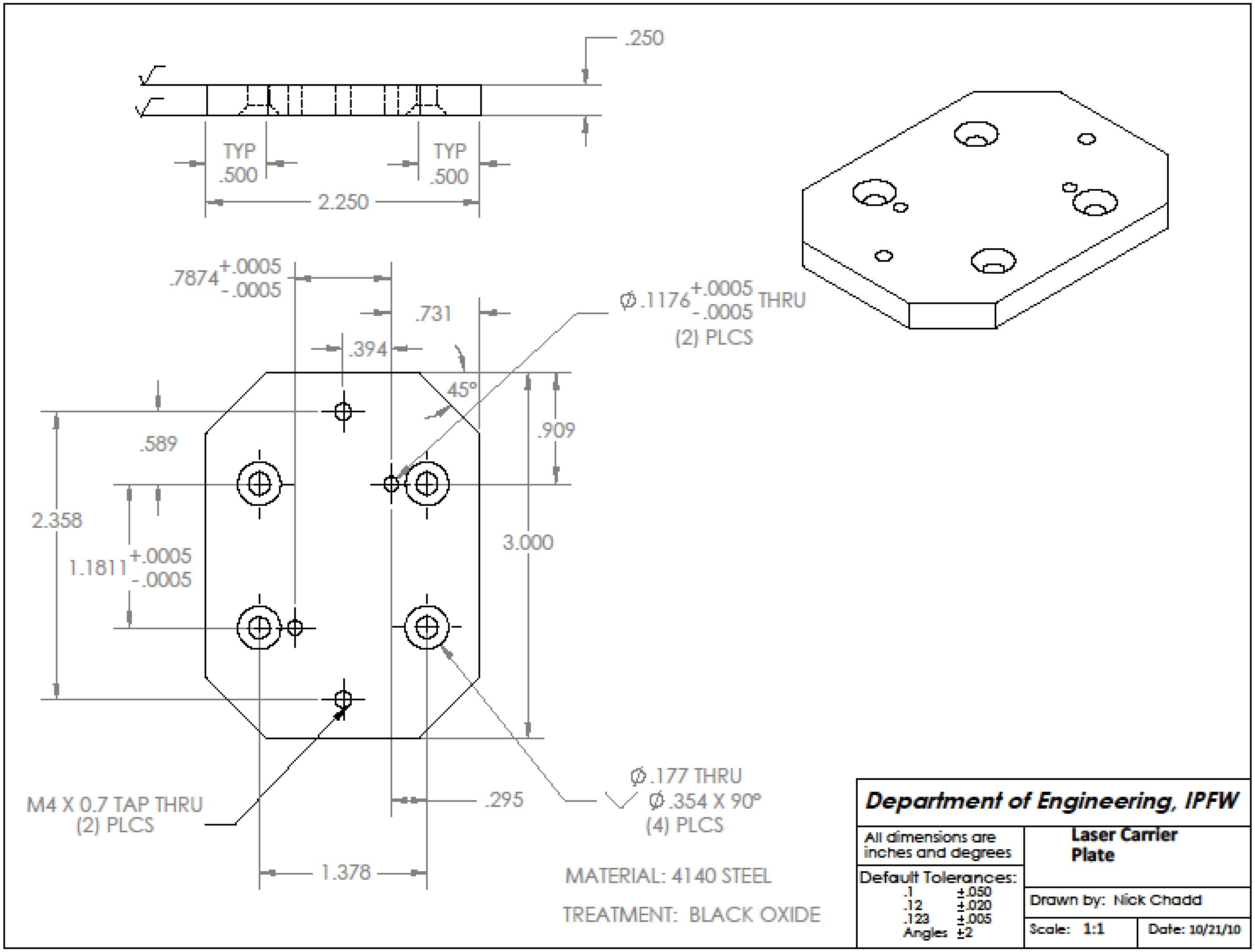


∅.250 CORNER RELIEF
.585 DEEP FLAT BOTTOM
TYP 2 PLCS
R.125
.275
.550
5/8-24 UNEF-2B THREAD
THRU TO CAVITY
.250 TYP
.250 TYP
3.875
3.375
1/4-20 UNC TAP .500 DEEP TYP (8) PLCS
.250
.188
.188
1.050
.675
2.520 +.002 -.002
1.181 +.001 -.001
1.438
.225
.125
2.000 +.001 -.001
2.585
.186
3.25
3.375
1.125
1.125
2.250
R.188
.189
1.125
1.546
.378 +.002 -.000
1/4-20 UNC TAP 1.00
DEEP TYP (4) PLCS
.189
.378 +.002 -.000
1.188
1.188
MATERIAL: 4140 PREHARD
TREATMENT : BLACK OXIDE
Department of Engineering, IPFW
All dimensions are inches and degrees
Default Tolerances:
.1 ±.050
.12 ±.020
.123 ±.005
Angles ±2
Base Plate
2.5 x 5.25 Heat Sink
Drawn by: Shane Carey
Scale: 1:2
Date: 9/10/2010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TYP .500
TYP .500
2.250
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.731
.394
45°
Ø.1176 +.0005 -.0005 THRU
(2) PLCS
.909
.589
2.358
1.1811 +.0005 -.0005
3.000
Ø.177 THRU
Ø.354 X 90°
(4) PLCS
M4 X 0.7 TAP THRU
(2) PLCS
.295
1.378
MATERIAL: 4140 STEEL
TREATMENT: BLACK OXIDE
Department of Engineering, IPFW
All dimensions are inches and degrees
Laser Carrier Plate
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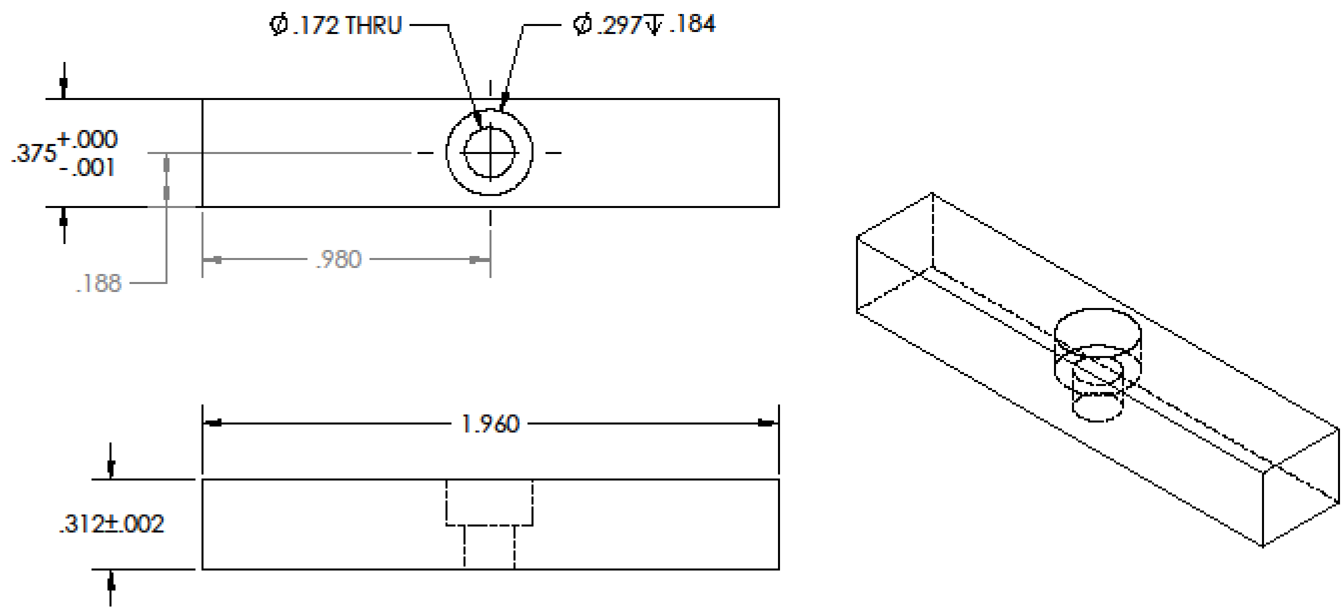
.12 ±.020
.123 ±.005
Angles ±2
Drawn by: Nick Chadd
Scale: 1:1
Date: 10/21/10



MATERIAL: 3/8 KEY STOCK

Department of Engineering, IPFW	
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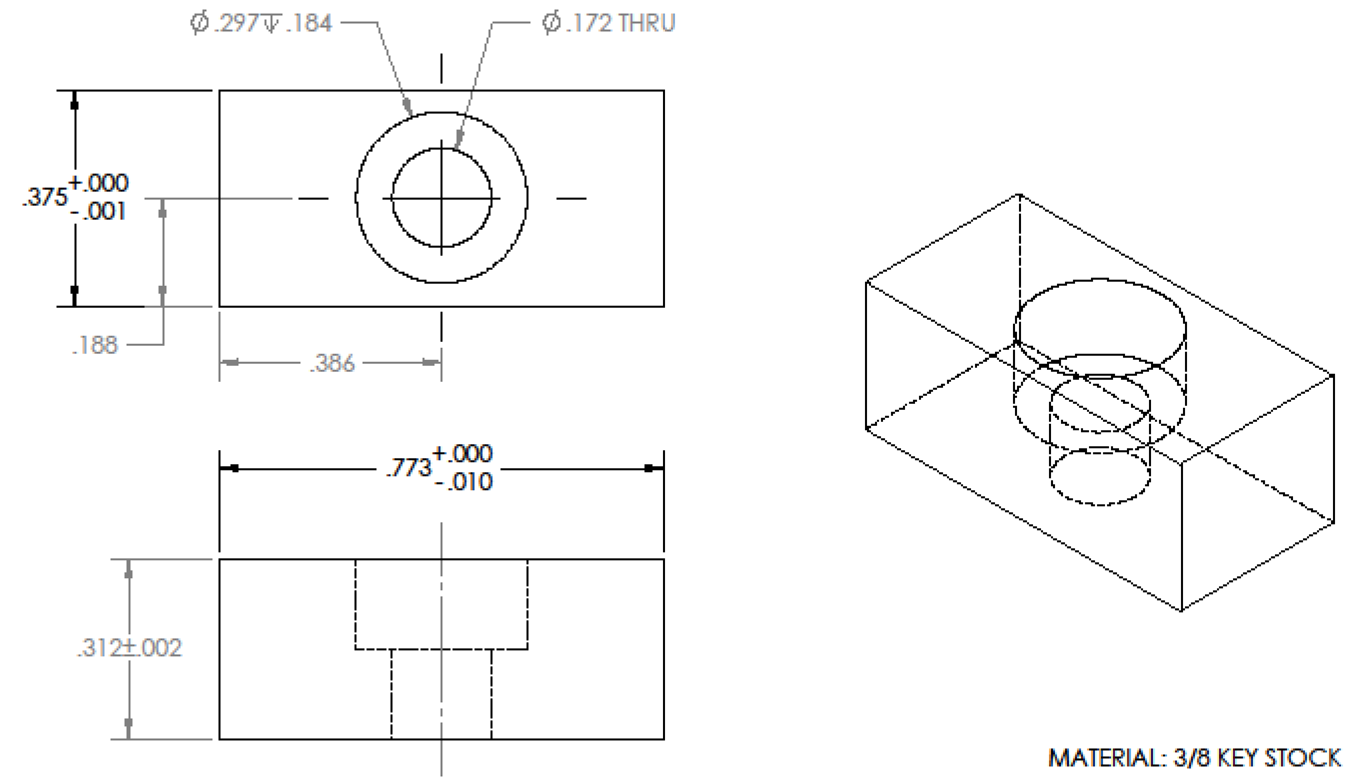
	Scale: 2:1 — Date: 10/21/10



MATERIAL: 3/8 KEY STOCK

Department of Engineering, IPFW

All dimensions are inches and degrees	**Side Key**
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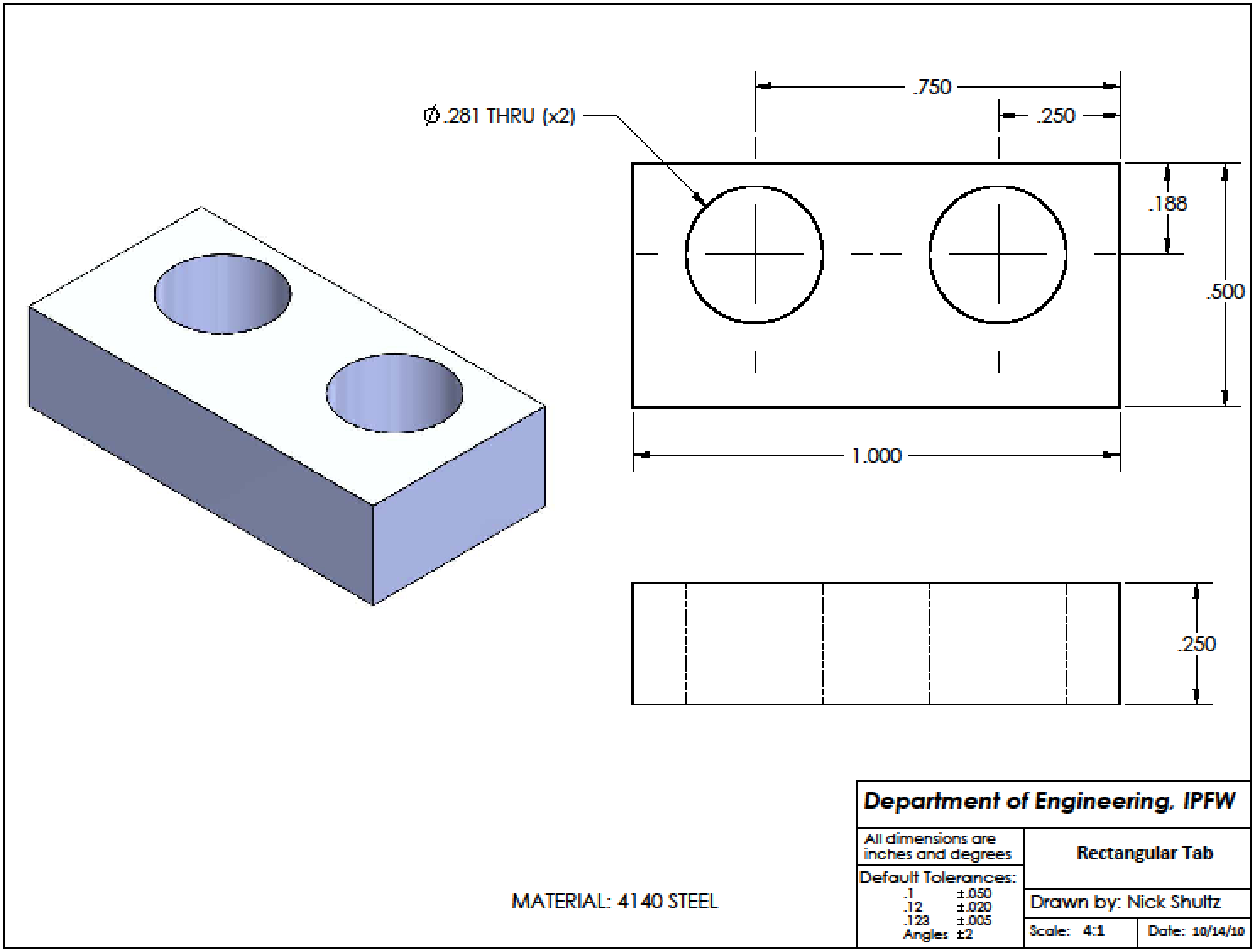
	Scale: 4:1 Date: 10/21/10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.250
.188
.500
1.000
.250
MATERIAL: 4140 STEEL
Department of Engineering, IPFW
All dimensions are inches and degrees
Default Tolerances:
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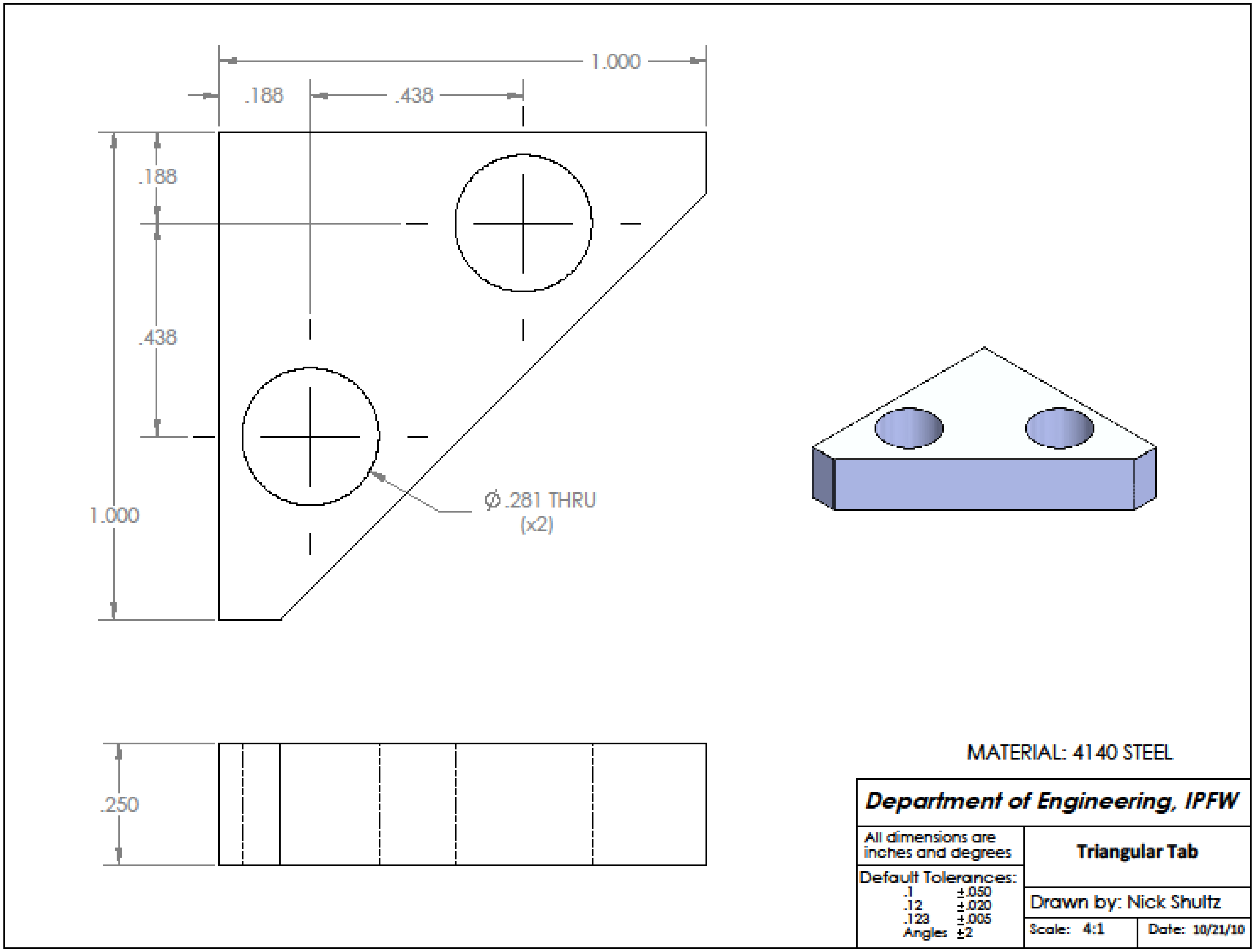
.12 ±.020
.123 ±.005
Angles ±2
Rectangular Tab
Drawn by: Nick Shultz
Scale: 4:1
Date: 10/14/10


1.000
.188
.438
.188
.438
1.000
Ø.281 THRU
(x2)
.250
MATERIAL: 4140 STEEL
Department of Engineering, IPFW
All dimensions are inches and degrees
Triangular Tab
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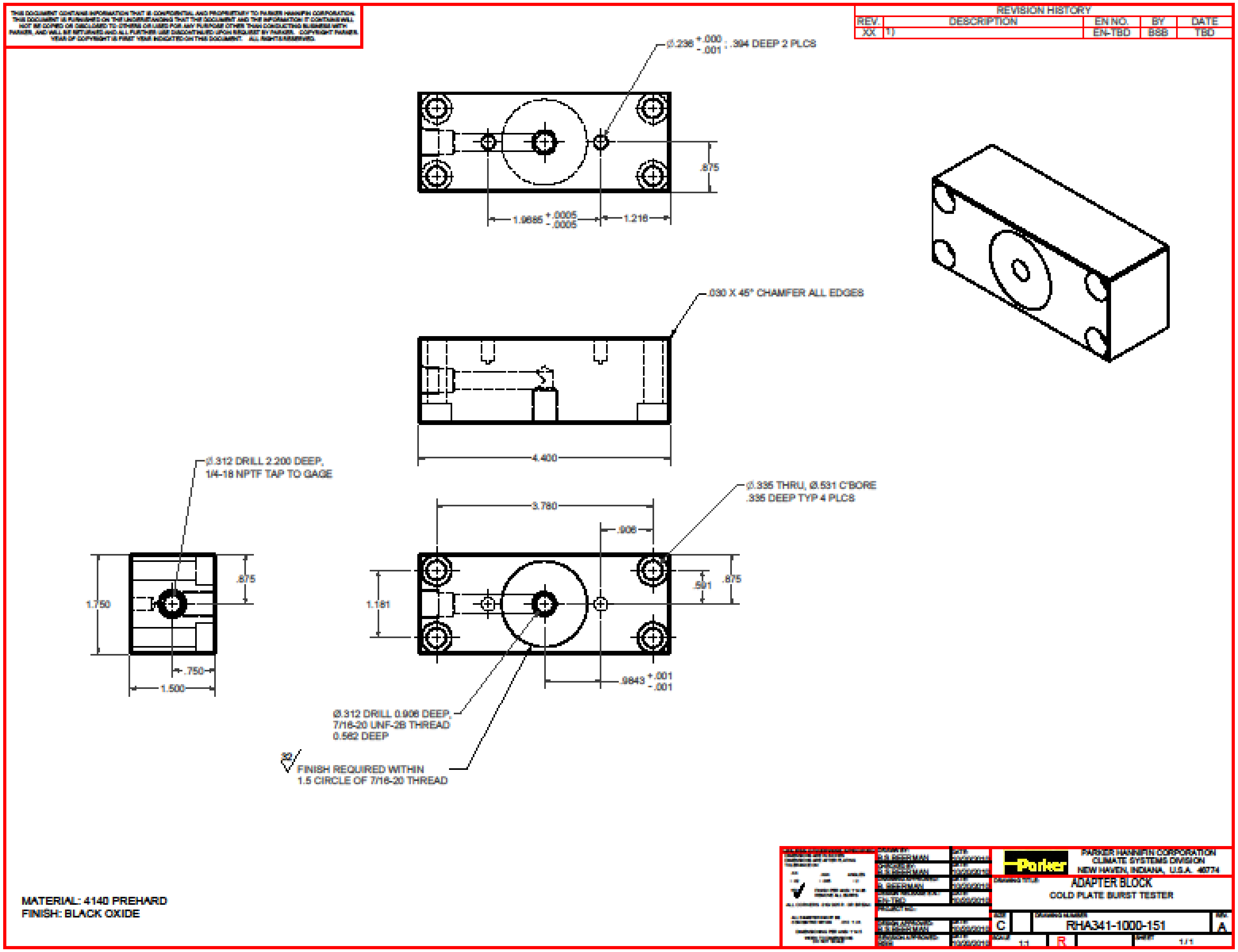
.12 ±.020
.123 ±.005
Angles ±2
Drawn by: Nick Shultz
Scale: 4:1
Date: 10/21/10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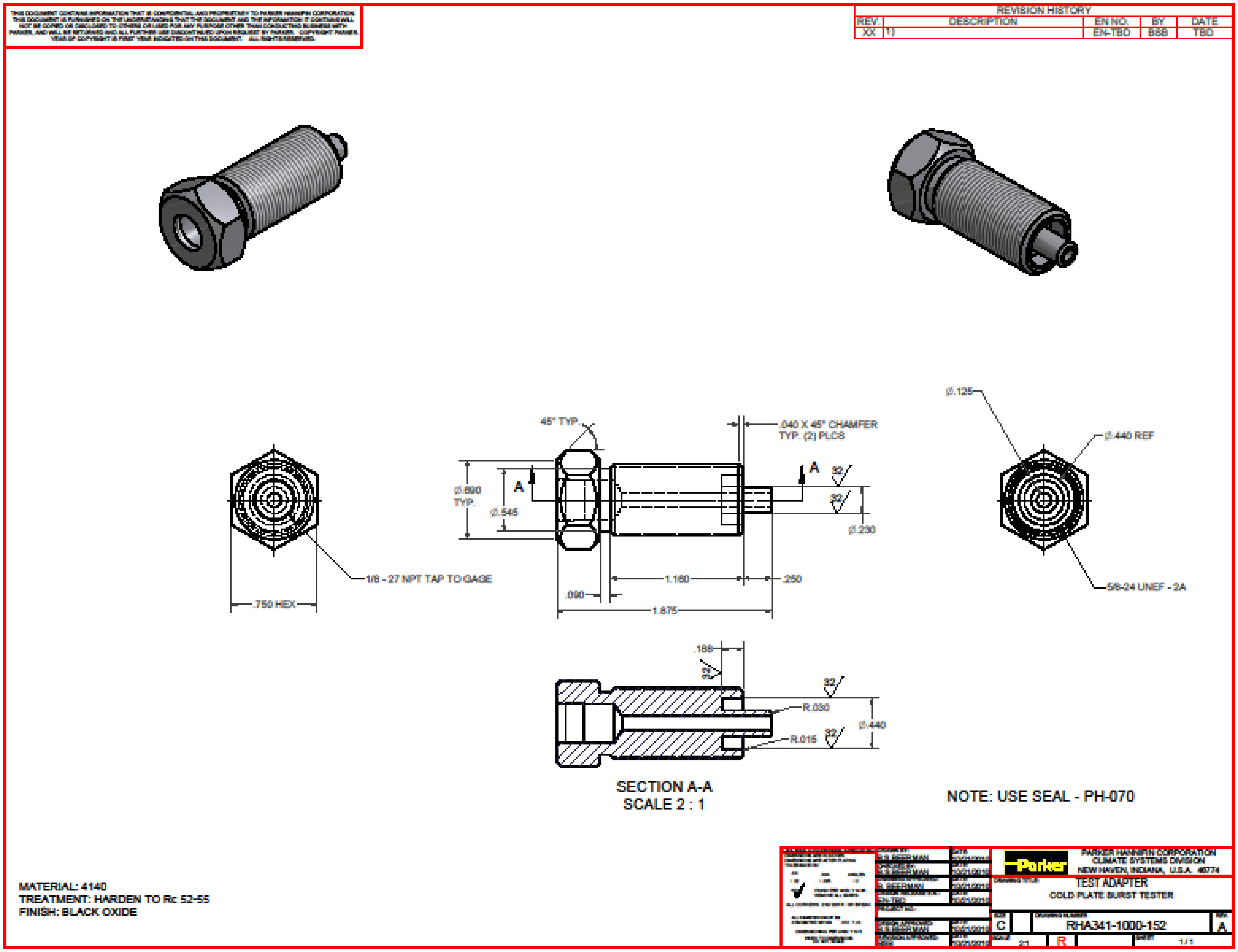
1.216
.030 X 45° CHAMFER ALL EDGES
4.400
Ø.312 DRILL 2.200 DEEP,
1/4-18 NPTF TAP TO GAGE
Ø.335 THRU, Ø.531 C'BORE
.335 DEEP TYP 4 PLCS
3.780
.906
1.750
.875
.750
1.500
1.181
.591
.875
.9843 +.001 -.001
Ø.312 DRILL 0.906 DEEP,
7/16-20 UNF-2B THREAD
0.562 DEEP
32
FINISH REQUIRED WITHIN
1.5 CIRCLE OF 7/16-20 THREAD
MATERIAL: 4140 PREHARD
FINISH: BLACK OXIDE
B.S. BEERMAN
B.S. BEERMAN
B. BEERMAN
EN-TBD
B.S. BEERMAN
PARKER HANNIFIN CORPORATION
CLIMATE SYSTEMS DIVISION
NEW HAVEN, INDIANA, U.S.A. 46774
ADAPTER BLOCK
COLD PLATE BURST TESTER
C
RHA341-1000-151
A
1:1
R
1/1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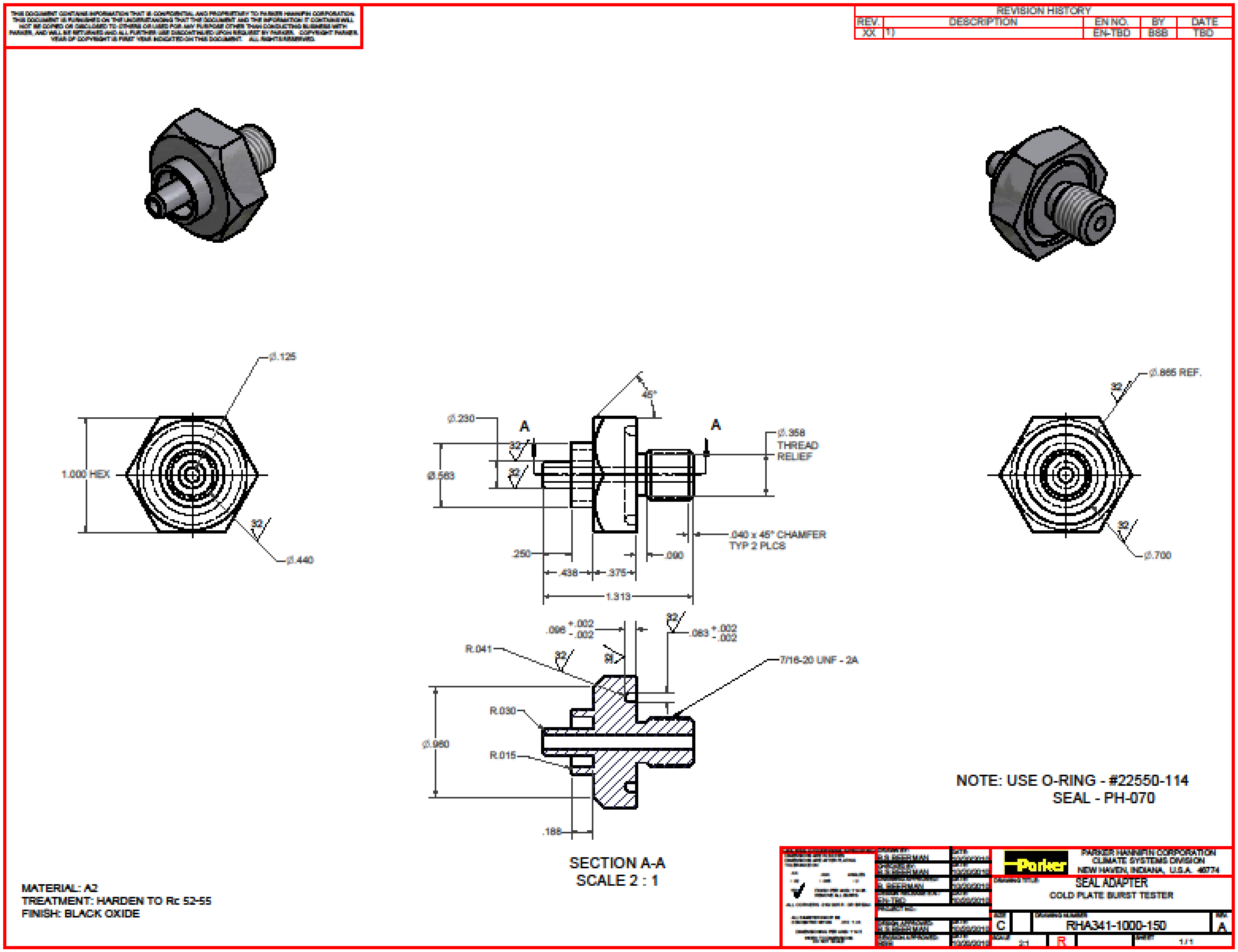
Ø.440 REF
Ø.690 TYP.
Ø.545
A
32
Ø.230
1/8 - 27 NPT TAP TO GAGE
.750 HEX
1.160
.250
.090
1.875
5/8-24 UNEF - 2A
.188
R.030
R.015
Ø.440
SECTION A-A
SCALE 2 : 1
NOTE: USE SEAL - PH-070
MATERIAL: 4140
TREATMENT: HARDEN TO Rc 52-55
FINISH: BLACK OXIDE
Parker
PARKER HANNIFIN CORPORATION
CLIMATE SYSTEMS DIVISION
NEW HAVEN, INDIANA, U.S.A. 46774
TEST ADAPTER
COLD PLATE BURST TESTER
C
RHA341-1000-152
A
2:1
1/1


REVISION HISTORY
REV.
DESCRIPTION
EN NO.
BY
DATE
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BSB
TBD
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32
Ø.440
Ø.230
A
A
45°
Ø.563
Ø.358
THREAD
RELIEF
.040 x 45° CHAMFER
TYP 2 PLCS
.250
.438
.375
.090
1.313
32
Ø.865 REF.
Ø.700
.098 +.002 -.002
.083 +.002 -.002
R.041
7/16-20 UNF - 2A
R.030
Ø.960
R.015
.188
SECTION A-A
SCALE 2 : 1
NOTE: USE O-RING - #22550-114
SEAL - PH-070
MATERIAL: A2
TREATMENT: HARDEN TO Rc 52-55
FINISH: BLACK OXIDE
PARKER HANNIFIN CORPORATION
CLIMATE SYSTEMS DIVISION
NEW HAVEN, INDIANA, U.S.A. 46774
SEAL ADAPTER
COLD PLATE BURST TESTER
C
RHA341-1000-150
A
2:1
R
1/1